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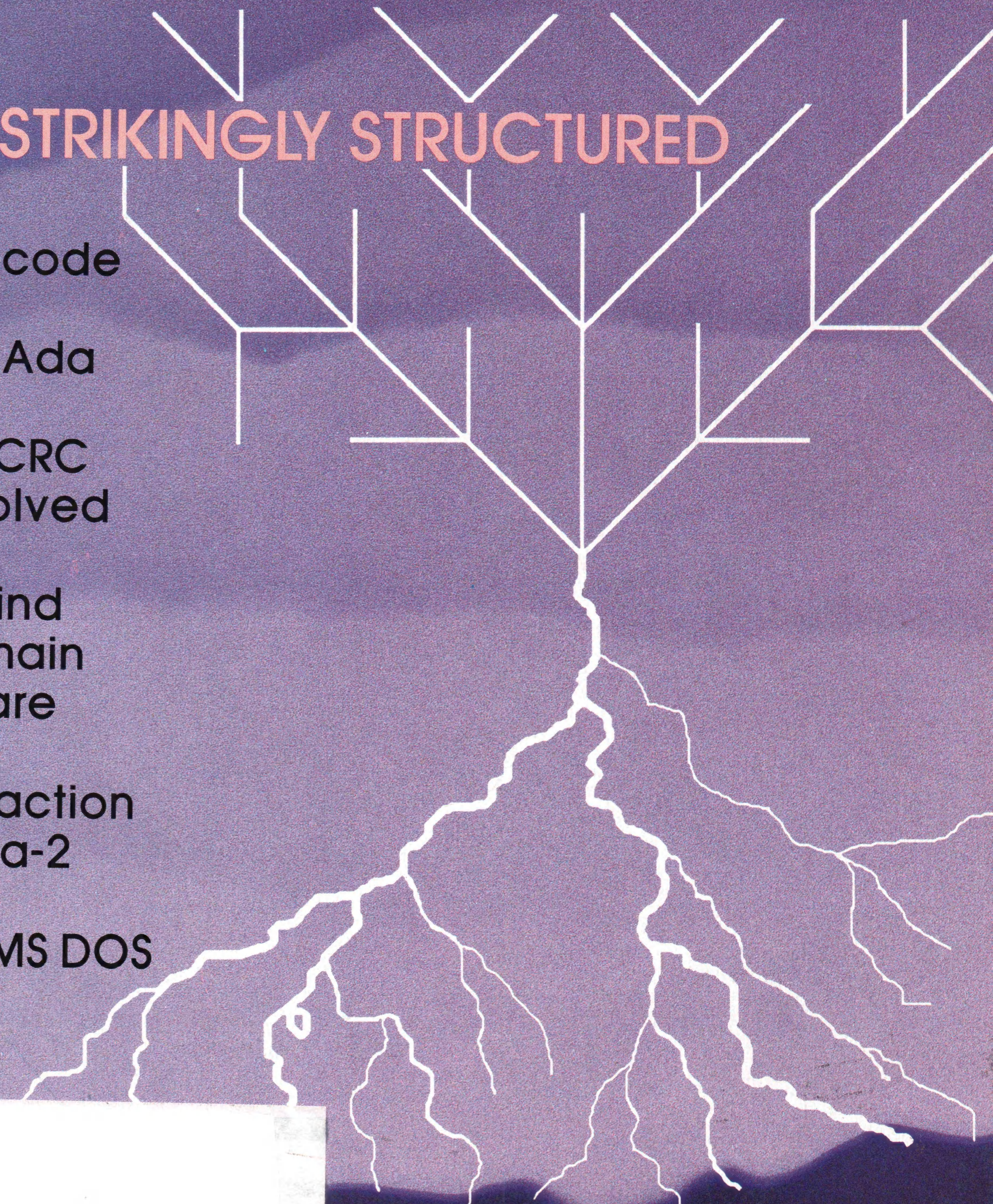
Dr. Dobb's Journal of Software Tools

FOR THE PROFESSIONAL PROGRAMMER



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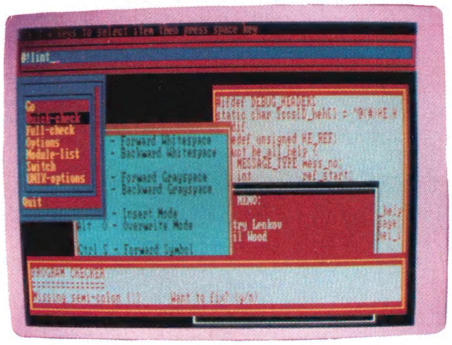

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FEBRUARY 1986 VOLUME 11, ISSUE 2

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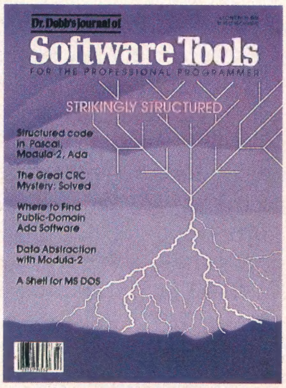


This month's cover was created by West and Moravec Designs. The image was created with MacPaint and printed on a LaserWriter. The background was created with an airbrush.

This Issue

Pascal, Ada, and Modula-2 are regarded as languages that encourage structured programming. This issue presents for each language some code that we hope you will find educational, useful, or both. We found Terry Ritter's explication of CRCs particularly enlightening.

Next Issue

For forty years, the fundamental algorithms underlying the design of computer software and hardware have been, with a few controlled exceptions, sequential. Now, even users are coming to see the benefits of background tasking and print spooling, while multiprocessor architectures are approaching practicality. But application concurrency and multiprocessor designs will only scratch the surface of parallelism until we recast algorithms in parallel. Is some new Knuth even now writing the book on parallel algorithms?

This is for all the power users technologies before they

Other than Steve Wozniak and Jonathan Rotenberg, there are probably only 2,998 personal computer users who qualify as trend setters. They're the people who owned Apples® when everyone else thought Apple® was a record label. People who were called hackers when a hacker was someone no one wanted to play golf with.

However many of you there are, this ad is for you. It's been designed and written to introduce you to a new technology without using superlatives or words like revolutionary. (We're saving those words for future ads targeted at the general consumer.)

The new technology is called the Softstrip™ System. This ad tells you what it's all about.

THE SOFTSTRIP SYSTEM ENCODES DATA ONTO PAPER.

Softstrip technology allows text, graphics, even digitized sound to be encoded on a strip of paper. Providing an alternative to magnetic media and telecommunications for the recording, distribution and retrieving of information.

These data strips, each a structured pattern of black and white rectangles that look something like a condensed bar code, can be encoded with special software and read with a scanning device called the Cauzin Softstrip System Reader. The reader optically scans the strip, translates its contents into 8-bit code and feeds it into a personal computer's serial or cassette port, enabling automatic, error-free entry of printed data without using a keyboard.

One Softstrip data strip, typically 5/8″ x 9½″, can contain up to 5,500 bytes of information. (For example, you could fit this entire ad on two strips.)

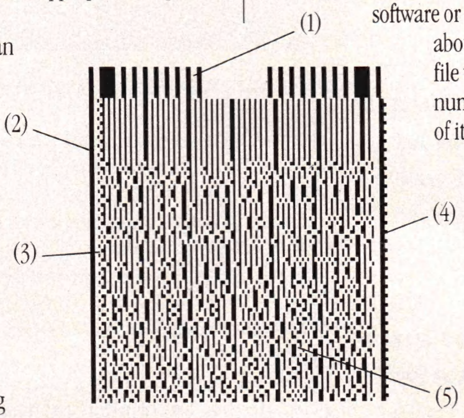
Strips can be printed by using a photographic negative (ideal for book and magazine publishers), or by using a laser or dot matrix printer and special software (appropriate for personal or business use).

If you want, you can generate strips that can be reproduced on a copier or versions that can't be. Either way, any data strip, whether it's printed in a newspaper, magazine or personal letterhead, can survive pen marks, scratches, even coffee stains.

Basically, anything you can put on a magnetic disk you can put on a Softstrip data strip, which should suggest numerous application possibilities.

Starting in the next two months, data strips will appear in magazines, journals and books. These strips will contain program listings, tables of contents, new product demonstrations and data.

Eventually, strips may be used for everything from bank statements to sheet music.

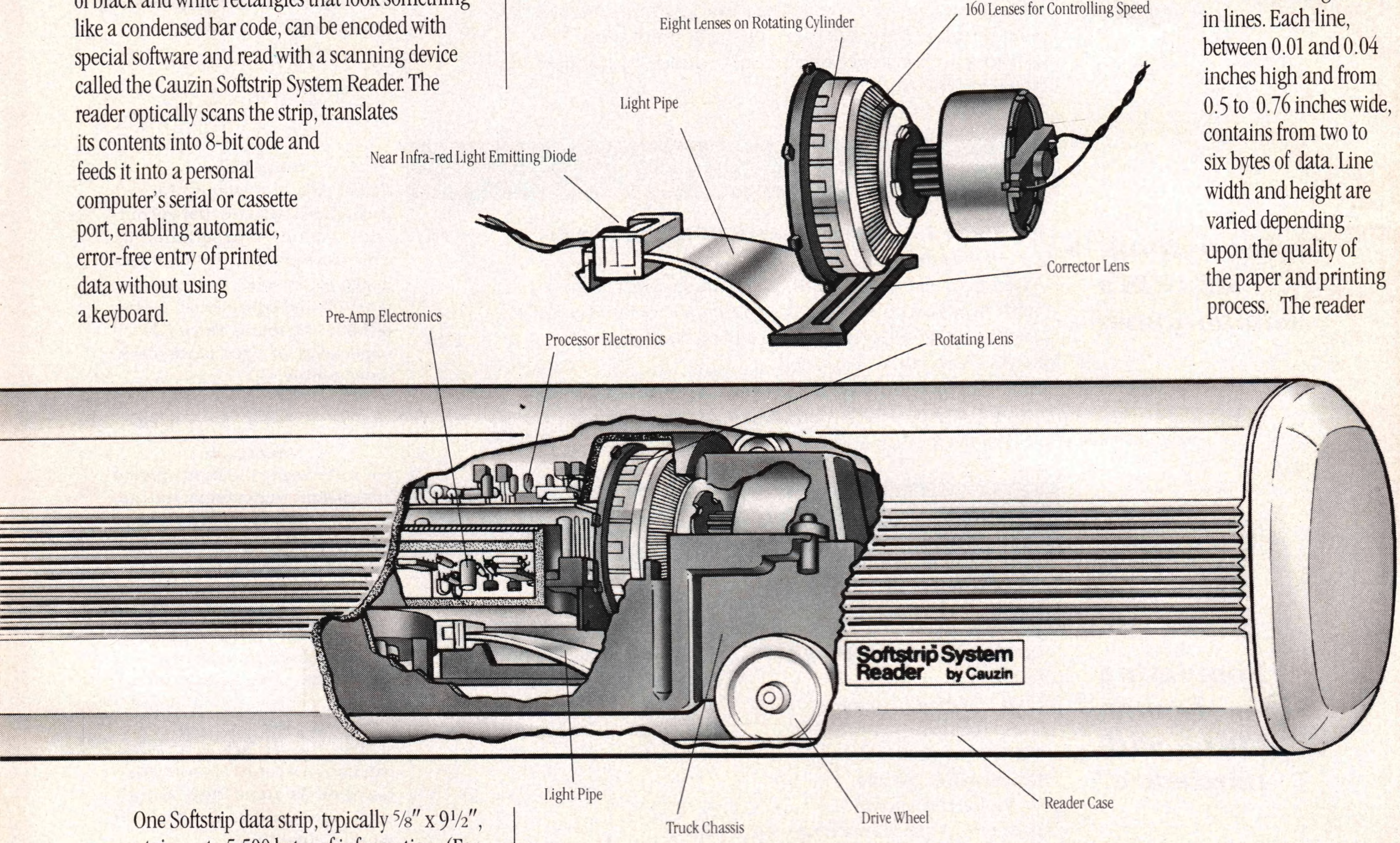


THE ANATOMY OF A STRIP.

A Softstrip data strip contains not only software or data, but also information about its content, including file types, file name and the number of strips. Because of its inherent technology, strips are as accurate as any magnetic medium. And they can be entered into an IBM PC,® Apple II® or Macintosh® computer using the same reader with only slightly modified communications software.

Strips encode data bit by bit using highly structured optical patterns. The bits are each composed of two rectangles called di-bits. They function as optical on/off signals. White/black equals 1. Black/white equals 0.

Data is organized in lines. Each line, between 0.01 and 0.04 inches high and from 0.5 to 0.76 inches wide, contains from two to six bytes of data. Line width and height are varied depending upon the quality of the paper and printing process. The reader scans each data line with a series of raster scans 0.0025 inches apart providing between four and sixteen scans per line.

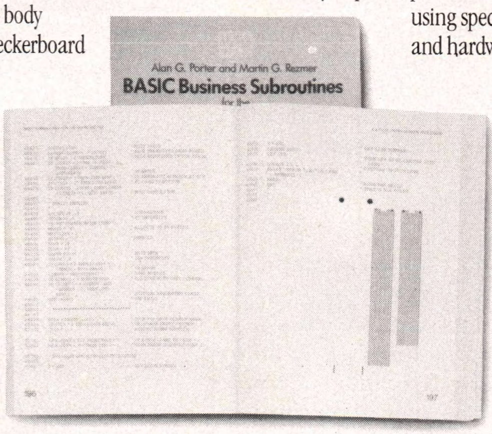


who want to know about new become household words.

A close-up view of a strip reveals five distinct sections. The header (1) at the top tells the reader the number of bytes in a line, the height of each line, and the paper to ink contrast level. Running vertically down the sides of the strip are the startline (2), the checkerboard (3) and the rack (4). They identify the boundaries of every horizontal line to be read. They also work in tandem to feed the reader alignment information.

Contained within the body of the strip, between the checkerboard and rack, is the file's data area (5).

Strip data accuracy is checked and error correction is provided by parity bits at the beginning and end of every data line, as well as by a strip checksum. There is also an optional 16 bit CRC. Combined, this design results in an undetected bit error rate of less than one bit error per 10,000,000,000 bits.



IT TOOK GUTS TO BUILD THE READER.

Rated for 25,000 reads, the reader is an equally impressive technology. It's composed of two key components: the case and the truck. While the case sits still, the truck moves uniformly down the length of the strip making a complete scan of the strip's di-bit lines every 0.0025 inches.

As the truck moves down the strip, it tracks its own lateral movement within five microns. Alignment is controlled by two servo mechanisms. As the truck moves, it illuminates the area to be scanned using near infra-red light beamed through a light pipe. (The infra-red technique permits the reader to see through colors, stains, and spills.)

The reader's optical scanning system, containing eight rotating cylindrical lenses and an aspherical corrector lens, forms an F.12 optical system with a depth of field between 0.05 and 0.08 inches. A set of 160 additional cylindrical lenses on the rotating lens allow the system to control scanning speed.

Inside the reader, the mechanical system uses six AGMA-7 high precision plastic molded gears to provide very accurate truck movement. One gear system even allows for a 4000 to 1 angle reduction with no backlash for corrector lens alignment.

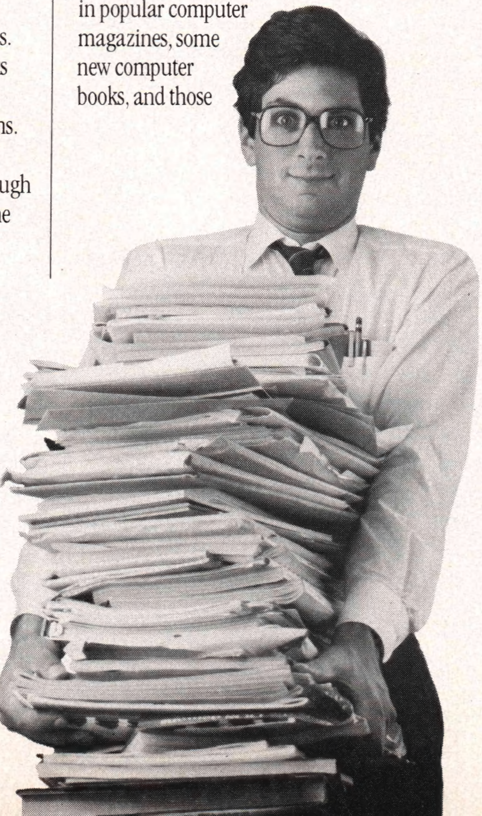
A TMS 7040 8-bit processor and Cauzin's own custom VLSI chip provide reader logic, control and communications using four nested phase locked loops and several hardware and software servos. The reader transmits data to the host at 4800 baud burst rates with throughput of 1500 baud.

HOW TO CREATE YOUR OWN STRIPS.

There are two ways to create Softstrip™ data strips. For large volume and greater density – up to 5500 bytes per strip – a film negative is created using special Cauzin software and hardware. This is ideal for book, magazine, newsletter, data base and commercial software publishers who can reproduce a strip in volume using web, offset, gravure or similar processes.

For personal or business applications, 500 to 1000 byte strips can be generated using Cauzin licensed software on dot matrix printers; up to 3400 byte strips can be generated using other Cauzin licensed software and laser printers.

In the next few months, you should start to see data strips appear in popular computer magazines, some new computer books, and those consumer ads we told you about earlier. They'll look exactly like the working strip you see here, a medium density strip with an ASCII text file on it.



Of course you'll be able to purchase a reader at most computer dealers. They'll be selling for about $200.00. Contact your dealer soon for a demonstration. Or call us directly at 203-573-0150.

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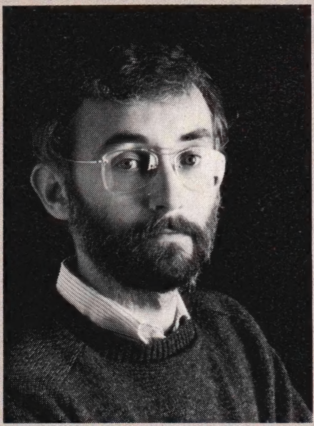
EDITORIAL



It's December 23 as I write this, and I'm hurrying to get this note to you before skipping out for the holidays.

When you read this, we expect to be in the middle of moving into our spacious new offices at 501 Galveston Dr., Redwood City, CA 94063. You should send any correspondence there.

Our editorial calendar (see below) indicates what topics we intend to go after this year. But the calendar doesn't tell the whole story. It doesn't include, for example, coverage of networking issues, cryptography, and memory-resident standards, all of which we'll be looking into in 1986, nor does it mention other topics that you will surely think of. Send us your ideas.

Allen Holub wanted to pass along this suggestion: *DDJ* writers and columnists are often more than happy to respond to letters from readers. Your chances of getting a response are increased if you include a self-addressed, stamped envelope. You can also reach our columnists via our Electronic Edition.

Frank DeRose, our special projects editor, is coordinating the editorial aspects of our new book line and of the Electronic Edition of *DDJ* on CompuServe. Frank spells out in this issue what we intend to do with our online publishing experiment. When you read this, some details of implementation will probably be different from what he says here, writing as he was before Christmas. Print has its limitations, which is why we're exploring electronic publishing. Log on to find out what's really happening there.

We're also doing the groundwork for an ambitious software review program. You won't see the results of this until midyear, but last August's C review and the review of programmable editors in November indicate the direction we'll be taking: comparative reviews of many products; more than one programmer evaluating the products; using the most useful and objective sets of benchmarks we can coax and coerce veteran programmers into developing for us; and regular updates and bug reports on the reviews themselves. We've wisely promoted Sara Noah Ruddy (our erstwhile editorial assistant) to assistant editor with responsibility for coordinating this whole review process.

The other member of the editorial staff whose name you should know is Vince Leone, our managing editor, who puts the pieces together every month. Vince, Sara, Frank, Allen, and I will probably be joined by one other editor in the next month or two. I'll let you know.

One final note: we owe you an article. In January, we promised a look at a program that ports between dialects of Pascal. This month was packed, and we didn't have room for everything; watch for it in March.

1986 editorial calendar
March: The future of programming; Article deadline: past.
April: AI. Deadline: past.
May: Designing usable software. Deadline: past.
June: Communications. Deadline: 3/1/86.
July: Forth. Deadline: 4/1/86.
August: C. Deadline: 5/1/86.
September: Algorithms. Deadline: 6/1/86
October: 80286/80386 programming. Deadline: 7/1/86
November: Graphics. Deadline: 8/1/86
December: Operating systems. Deadline: 9/1/86

Michael Swaine

Michael Swaine

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LETTERS

Columns

Dear *DDJ*,

Allen Holub's C Chest article on recursive descent parsing (September 1985) was very interesting but contained an inaccurate grammar that gives erroneous results such as:

2*3+1 = 8
(should be evaluated as
(2*3)+1 = 7)

6−5−4 = 5
(should be evaluated as
(6−5)−4 = −3)

A correct grammar for expressions is found, in one form or another, in every book on compiling. I will show how the rather unintuitive final form is reached by proceeding in small steps.

A very simple grammar is given by the following rules:

```
E ::= E A E | (E) | −E | n
A ::= + | − | * | /
```

where E and n stand for expression and number respectively, and A stands for arithmetic operator. This grammar is ambiguous, as 6−5−4 can be parsed in two valid (but different) ways:

(6−5)−(4)
(6)−(5−4)

In each case, the parenthesised symbols form an expression, and the two expressions are linked by an arithmetic operator. We need a rule to introduce associativity, i.e., to ensure the first parse of 6−5−4. Rule (5) in Figure 6 of the article attempts to do so but introduces the wrong associativity:

```
E ::= F−E
```

forces the incorrect parse

6−5−4=6−(5−4)

Inverting the order in rules (2) to (5) will solve the associativity problem. This leaves us with a second problem. We want both 2*3+1 and 1+2*3 to evaluate as 7. This is because in mathematics multiplication and division have a higher precedence than addition and subtraction. To achieve this we introduce two new nonterminals, *term* and *factor*. Roughly speaking, terms are things that get added (or by extension subtracted) together, while factors get multiplied (or divided). The resulting grammar is:

```
E ::= E+T | E−T | T
T ::= T*F | T/F | F
F ::= n | −n | (E) | −(E)
```

This grammar is correct. It will not parse 2*3+1 as (2)*(3+1) because that would be an expression multiplied by an expression, not one of the valid ways of forming an expression.

Though correct, this form is not suitable for parsing by recursive descent. There is no way to "get at" the first piece to start the recursion. The grammar given by Holub allowed us to start *expr( )* with (to evaluate 6−5−4):

```
lval = factor( );
lval −= expr( );
```

Our grammar would seem to require:

```
lval = expr( );
lval −= factor( );
```

So *expr( )* would call itself in an infinite loop. The grammar must therefore be modified as follows:

```
E  ::= TE'
E' ::= +TE' | −TE' | NULL
T  ::= FT'
T' ::= *FT' | /FT' | NULL
F  ::= n | −n | (E) | −(E)
```

E' and T' are the new nonterminals required to make the basic grammar parsable by recursive descent. They allow us to split off a piece to get started.

Note that the definition of a factor is unchanged, so the code for *factor( )* and *constant( )* will not need to be modified.

Mohamed el Lozy
Health Sciences Computing Facility
665 Huntington Ave.
Boston, MA 02115

DISnDATa

Dear *DDJ*,

In your November 1985 issue on page 89, you ran an ad for a disassembler written by C. W. Medlock of PRO/AM SOFTWARE. On the basis of claims made in the ad, I purchased this product for the price of $145.

To my sorrow, when I received this software and tried it, I found that, for the vast majority of programs, it does not correctly locate the data and code areas as claimed in the ad. Instead, it invariably outputs large segments of code areas as data. What is worse is that there are no switches in the program to override the automatic "algorithm" when this occurs, nor is there any provision for telling the program where the data and code areas are if, as is usually the case, you happen to know this information. The only recourse you have, as described in the 20-page manual supplied with the program, is to do a series of binary

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LETTERS:
(Continued from page 8)

patches to the executable file for each area of code the program doesn't find. Needless to say this is a lengthy and time-consuming process. In addition, I found that for some input programs the disassembler hangs the computer so that a reboot is necessary.

Gerald Coquin
132 Rotary Dr.
Summit, NJ 07901

Of Interest

Dear *DDJ*,

In reading through the November 1985 issue of *Dr. Dobb's Journal*, I ran across a notice concerning our C-Link product. We are pleased, of course, to be mentioned in your publication; however, the information in Alex Ragen's Of Interest column is out of date.

During the past few months since the last news release was issued, we have changed our market strategy in response to the lack of Unix and C experience among users. The main focus of our marketing effort is to use C-Link as a tool to provide a translation service. We will continue to offer C-Link as a product but only to users willing to be trained in its usage. When sold in this manner, the cost is $4,995 plus $195 for additional run-time licenses.

Please contact me directly if you would like more information about either the C-Link product or service.

James R. Getzinger
Software Manufacturers Inc.
20720 S. Leapwood Ave.
Carson, CA 90746

Fgrep

Dear *DDJ*,

I wish to express my appreciation for the excellent article by Ian Ashdown in the September 1985 issue covering FGREP.C. This article has been very enlightening to me in actually applying the algorithms to construct finite state automata as outlined in the Aho and Ullman book *Principles of Compiler Design* and referred to by Mr. Ashdown in the discussion of the FGREP.C program.

I have adapted the Unix C program for the BDS compiler and library for my Z80 machine and in this process have encountered two items in the source program that I wish to comment upon—they may be important because of their possible nonportable nature.

First, I would like to take exception with Mr. Ashdown's use of the definition of TRUE as (−1). I suggest that this usage is not in the "spirit of C" and is out of context with the clearly defined usage of relational and logical operator returns in C, which K & R guarantees to be 1 for TRUE and 0 for FALSE when making explicit comparisons. Mr. Ashdown's use of (−1) may be a legacy of assembly-language programmers, and its use in the program on a stand-alone basis poses no problems, but it certainly plays havoc if other standard headers are used and TRUE gets redefined. For levity and condign punishment, I suggest that Mr. Ashdown compile and run the program shown in Table 1, below.

Second, I had a problem with the *stoupper( )* routine in that the resulting string lost its first letter in being put to uppercase. It is suggested that this routine is nonportable and compiler-dependent. The problem stems from the intuitive use of post-increment on the left side of an assignment expression, expecting the assignment to be made before the post-increment. The strict constructionist interpretation of operator precedence has the post-decrement operator higher than assignment and has the compiler reduce the left side of the expression below before the assignment operation is performed:

```
*temp++ =
    toupper(*temp);
```

This results in a loss of a character. The order of evaluation is not defined by K & R in this case, and few books on C discuss these sorts of statements wherein the order of evaluation is not defined. These are pernicious when they seem so intuitive. Other cases, such as:

```
array[x] = ++x;
```

which is not defined is, I suggest, easier to recognize intuitively and less likely to be applied by a C programmer.

It may be of use for *DDJ* to list, for example, these cases of evaluation-sensitive expressions that are not defined in K & R and lead to nonportability.

Justin Farnsworth
65 rue Chauveau
92200 Neuilly, France

```
#define        TRUE        (-1)
*define        FALSE       0
main( )
{M8
     if(TRUE == !FALSE)
          puts("\nAll's right with the world.");
      else
          puts("\nThe world is upside down.");
}
```

Table 1

Unix

Dear *DDJ*,

I am amazed at the number of products, advertised in your magazine and elsewhere, that are designed to make MS DOS look more like Unix. So far, I've seen a variety of text editors made famous under Unix, a plethora of C compilers, a word processing package that bears strange similarities to *nroff*, and an implementation of *make*. There is reportedly a package that implements the Bourne shell and comes with a variety of utility programs, such as *diff* and *grep*. You can even buy a LALR(1) parser generator (a freebie under Unix called *yacc*). All of this is in addition to the many features of MS DOS itself that were, uh, borrowed directly from Unix without so much as one word of acknowledgement.

One could spend several thousands of dollars equipping an MS DOS machine with all these programs, and the result would still not approach the power of Unix. A purchase of Xenix seems to me to be the best buy in the software market. It is the most useful piece of bundled software I've seen.

David F. Ziffer
Software Development Systems
3110 Woodcreek Dr.
Downers Grove, IL 60515

DDJ

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2 86 DDJ

VIEWPOINT

Sixth Generation Minds

Our man from muppetland returns with an entourage including strange attractors and motorboats on mercury pools.—ed.

How might we simulate actual human cognition via new kinds of hardware?

A clue comes from the work of Erich Goldmeier, whose essentially gestalt investigations in visual perception were a response to "the frustrating effort to teach pattern recognition" to computers. He found that the distinctions humans make between figure and ground, matter and form, norms and distortion, etc., cannot be the result of examining the features of the figures or any formal aspects of the figures. Instead, Goldmeier believes, there are prototypical or archetypal figures existing somehow at the neurological level, such as "regions of resonance" in the brain.

All this fits with Michael Doherty's latest *DDJ* article citing the works of Rosch, Nelson, and Palermo, which suggests that concepts cannot be broken down into a list of features via reductionistic techniques and then recombined. In this view, objects are categorized not by tabulating features but in terms of measured distance from some mental ideal or type. Doherty also mentions the linguistic curiosities known as "squishes." The facts that the gerund "his going" can be used in the same positions as a normal noun phrase and that it can be placed along a continuum of "nouniness" implies that one can't assign linguistic terms to discrete categories and state hard rules based on membership in the categories.

But how does all this relate to building a computer whose workings parallel those of the brain?

Until recently, it was thought that the firings of neurons in the brain could be likened to the activity of flip-flops in a computer. Now it appears that large groups of neurons work in unison, interacting via complex electromagnetic fields—which could explain the "regions of resonance"required by Goldmeier's view and also such phenomena as associative memory and the ability of the brain to recognize internally complex stimuli (such as a friend's face) almost instantly.

In one model, which is based on the work of such researchers as E. Roy Johns of the New York University Medical Center and W. Ross Adey of the Loma Linda Veterans Administration Hospital, neurons behave as complex nonlinear oscillators. This places the problem of understanding the collective behavior of neurons in the realm of chaos theory, which describes mathematically systems that shift from periodic to nearly chaotic behavior—such as the way a stream of air becomes turbulent near an airfoil—that are best described via the mathematical entities known as "strange attractors."

Unlike what happens in more tractable systems, when one changes input to a strange attractor slightly one ends up with a wildly different output. Erol Basar of the University of Physiology in Lübeck, West Germany, plotted the amplitudes of two brain frequencies and found their relationship to be that of a strange attractor. Maybe free will is a strange attractor?

In any case, building a "field-effect" computer based on nonlinear oscillators ought to be a technological nightmare. Eric J. Lerner says that it could be done in one of four ways: (1) microwave circuits built from conventional components; (2) Josephson junctions, which are natural nonlinear oscillators in the microwave region; (3) using an optical processor, increasing the electromagnetic frequencies of individual transmitting units; (4) using some kind of molecular processor such as those projected for future "biochips."

One could think up some additional, perhaps less plausible, versions of such a computer: a swimming pool filled with liquid mercury, the surface of which is disturbed by thousands of toy motorboats with broken propellers and faulty engines (the "nonlinear accelerators"); or a soundproofed room filled with thousands of microcomputers fitted with speech recognition/production devices squawking at each other at various frequencies.

But is it worthwhile?

The successes of limited expert systems demonstrate special deficiencies in human cognition. As Doherty wrote, "The strange fact about AI has always been that it's easier to simulate an expert than to simulate the common sense of a five-year-old." The tremendous contextual knowledge that children possess is wired into the brain along with the innate capacity to understand the grammars and semantics of natural language. These abilities have been genetically handed down to us by our ancestors, useful evolutionary "inventions" by the ubiquitous DNA molecule to keep itself from extinction. Thus, the amount of learning required in these cognitive areas is minimal, as they are processes acquired over time in a way that is "transparent to the user."

But we should not feel too complacent. The other side of the coin—learning new forms of knowledge and mastering them as an expert—is a domain easily dominated by computers. If you or I were to memorize a few hundred rules and apply them logically, we could get straight As on MIT calculus finals, but we are unlikely just now to run off to examine Slagle's hundred rules. The future of the art and science of expertise belongs to machines, not to human beings.

DDJ

by Richard Grigonis

Richard Grigonis is employed by Children's Television Workshop. He is best known to DDJ readers for his articles on fifth and sixth generation computing and the Grigonis-Doherty debate these articles precipitated.

DDJ ON LINE

DDJ Goes On Line

On January 1, the Electronic Edition of *Dr. Dobb's Journal* appeared on CompuServe. Through the Electronic Edition *DDJ* will offer the following:

• We will make available in our data libraries most of the listings that appear in the articles and columns of *Dr. Dobb's Journal* every month. The data libraries will also contain selections from some of our more popular back issues and occasionally articles and listings that have not appeared in the magazine.

• Some of our more significant programs will be available through Softex in the near future. Softex is CompuServe's electronic software exchange, a menu-driven program that allows users to purchase and download software though the network.

• We will maintain a display area where CompuServe users can read abstracts of the material in the current issue. The display area will also contain general magazine information, such as our editorial calendar, writers' guidelines, and information for advertisers.

• We will compile lists of the commercial software development tools available to microcomputer programmers. We will also compile selected bibliographies and give capsule reviews of newly released books.

• We will provide a messaging facility with columnists and other SIG members.

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• We will take subscriptions for *Dr. Dobb's Journal*, the magazine. We will also provide a way for readers to register circulation complaints.

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DDJ

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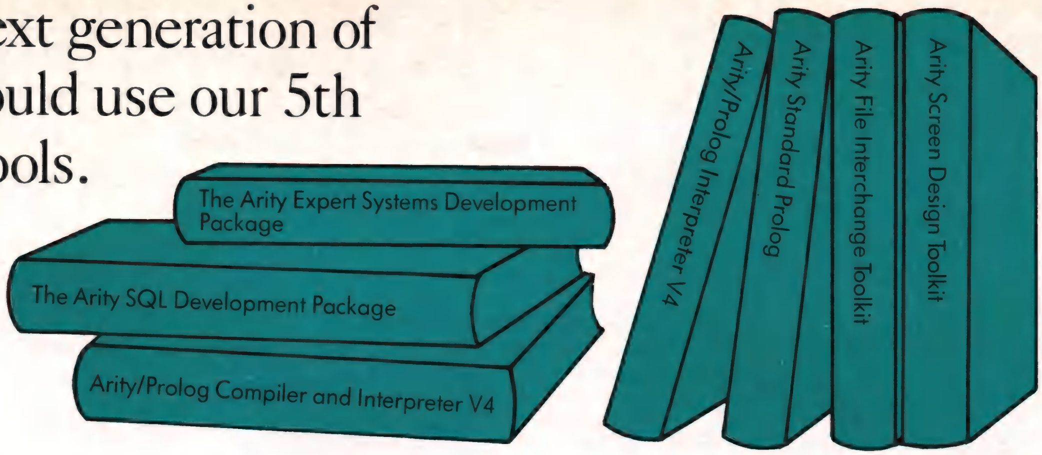

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A New Shell for MS DOS (continued)

This month's column continues with the MS DOS shell. Last month I described how to use the shell and printed Listing One, the shell itself. This month, because the various subroutines that make up the shell are commented well enough so that additional comments here are unnecessary, I'll discuss only the shell's organization at a reasonably high level and those subroutines whose function is not immediately evident. Refer to the listings for more details. This month's listings (Listings Two, Three, Four, and Five, pages 66–74) are the history, shell variables, alias support, and a couple minor support routines. Next month I'll finish up the shell with another collection of miscellany.

A bug was found in last month's listing after the issue went to press. As printed, the shell would try to expand * or ? even if these characters were in a quoted string. To fix this problem, replace the subroutine

```
has_wild()
```

(line 348) with the code shown in Table 1, page 18.

This morning I dumped all the various shell listings out on my printer for the first time. I admit I'm surprised by the number of pages now piled on my desk (for all that, sh.exe is only 28,906 bytes compared with 23,210 bytes for command.com). Anyway, for both my own sanity and to make everyone's life a little easier, I've compiled a cross-reference of all the shell-related subroutines (Table 2, page 18). The table shows the subroutine name, the listing number (and month of publication), and the line number on which the subroutine starts. Next month's listings are included in the table as are subroutine-like macros.

by Allen Holub

Compiling the Shell

The shell was compiled using the most recent version (3.0) of the Microsoft C compiler. (I am not as impressed with the compiler as many other reviewers seem to be; there will be an extensive review of the compiler in this column next month.) I've tried to restrict myself to those library subroutines that are readily portable to other compilers. Most of the system-level routines (*chdir( )*, *getcwd( )*, and so on) are simple BDOS calls anyway, so it shouldn't be too hard to write them if you don't have them already. All the library routines used are listed in a block of externs on lines 110–123 of Listing One.

Three routines may cause trouble if you're not using the Microsoft compiler. These are *signal( )*, which lets you handle a ^C, and the environment manipulation routines *getenv( )* and *putenv( )*. If you need a *signal( )*, I'd suggest using Ray Duncan's *break.asm* (*DDJ*, September 1985, pp. 119–121), which is functionally very similar to *signal( )*. (*Break.asm* sets a global flag rather than calling a subroutine when ^C is encountered.)

Getenv( ), used to examine an environment string, is relatively straightforward to write. A pointer to the environment string is part of a program's PSP. [For more information about the PSP, see *The Peter Norton Programmer's Guide to the IBM PC* (Microsoft Press, 1985) p. 260f.] In any event, Lattice, Microsoft, and Aztec all have a *getenv( )* in their libraries. Unfortunately, of the three, only Microsoft has a *putenv( )*, and adding an environment string is a harder problem, mostly because a child process must inherit the shell's environment. The various fork/spawn functions have to be rewritten to pass the new environment to the child. If anyone has done any of this, please send me your routines, and I'll print them. Lacking that, I'll try to write them myself within the next few months.

The shell modifies only two environment strings. CMDLINE holds the full 2,048-byte command line, and SHLEV holds the current shell nesting level. If you can live without these, then you don't need a *putenv( )*. An alternative approach is to use the Intra-Application Communications Area supported by DOS. The ICA is a 16-byte block at addresses 0000:4f0 to 0000:4ff, reserved by DOS so that programs can communicate with each other (that is, DOS promises not to trash it for you). The current shell level and a long pointer to the command line buffer could be put into the ICA and then accessed by a child process instead of using environment variables. You should probably put a checksum in the ICA as well, to make sure that another program hasn't modified it.

I've used the *void* type in the shell so that a warning will be printed if you use the return value of a subroutine that doesn't return a value, though I haven't used any pointers to *void*. I'd suggest putting a

```
typedef int    void;
```

into your stdio.h file rather than dispensing with the *void* declarations—your program will be more portable that way. Microsoft also supports strong type checking, so I've been using it too. Strong type checking is turned on by including a type list as part of an extern statement. For example:

```
extern int fopen( char *, char * );
```

will do all the usual things, and a

(Continued from page 16)

warning will be printed if the return value from *fopen* isn't put into an *int*. In addition, warnings will be printed if *fopen* is called with anything other than two, character-pointer arguments. A subroutine with a variable number of arguments can be declared:

```
extern void printf( char * , )
```

Here, *printf( )* must have one character-pointer argument, but this one can be followed by zero or more additional arguments of indeterminate type. *Printf( )*s return value (which is garbage anyway) can't be used for anything because of the *void*. If you're not using a compiler that supports strong type checking, don't enter the type list when you type in the code. All the extern statements are grouped near the top of every module so that you can find them easily.

Another potential portability problem is the enumerated type (TOKEN) used on lines 193—208 of Listing One. You can replace the TOKEN declaration with

```
typedef    int TOKEN;

#define    ALIAS      0
#define    CD         (ALIAS +1)
#define    CMD        (CD +1)
#define    EXIT       (CMD +1)
#define    HISTORY    (EXIT +1)
           .
           .
           .
```

One final portability issue: I've used both bit fields and explicit initializers all over the place. To my mind, these are both part of the C language, and I wouldn't consider dispensing with them any more than I'd consider not using ++ or pointers. Just because a few turkey compilers (such as BDS) can't compile a program written in C, I'm not going to deliberately cripple my own programs by not using perfectly legitimate constructs. This is an MS DOS shell anyway, and most MS DOS compilers support bit fields and initializers (if yours doesn't, you should consider getting another compiler). Those that don't support bit fields will just ignore the

```
int      has_wild( bp )
register char *bp;
{
         /*      Return true if the string has a * or ? in it
          *      Does not recognize a * or ? in a quoted string.
          */

         register int inquote = 0;

         for( ; *bp ; ++bp )
         {
                 if( *bp == '\\' && *(bp+1) )
                     ++bp ;

                 else if( ISQUOTE(*bp) )
                     inquote = inquote;

                 else if( !inquote && (*bp == '*' || *bp == '?') )
                     return 1;
         }
         return 0;
}
```

Table 1

name	listing #	month	module	line number
typedef TOKEN	listing 1	(jan)	sh.c	193
typedef VAR	listing 3	(feb)	var.c	29
add_entry	listing 7	(mar)	dir.c	247
add_hist	listing 2	(feb)	hist.c	72
alias	listing 1	(jan)	sh.c	1237
cd	listing 1	(jan)	sh.c	1313
clab	listing 7	(mar)	dir.c	349
cmds	listing 1	(jan)	sh.c	1417
cmp	listing 7	(mar)	dir.c	359
command_inpu . . .	listing 1	(jan)	sh.c	285
copy_path	listing 7	(mar)	dir.c	327
cptolower	listing 2	(dec)	cptolow.c	1
cpy	listing 3	(dec)	cpy.c	1
cursize	listing 4	(dec)	vidbios.c	49
del_dir	listing 7	(mar)	dir.c	412
DIAG	listing 1	(jan)	sh.c	156
digit	listing 1	(jan)	sh.c	251
dir	listing 7	(mar)	dir.c	431
dirtoa	listing 7	(mar)	dir.c	200
disk_present	listing 1	(jan)	sh.c	1266
doargs	listing 1	(jan)	sh.c	1100
docmd	listing 1	(jan)	sh.c	883
doenv	listing 1	(jan)	sh.c	1359
efgets	listing 5	(dec)	efgets.c	393
eget_hist	listing 2	(feb)	hist.c	169
egets	listing 5	(dec)	efgets.c	138
ENDTRACE	listing 1	(jan)	sh.c	151
errmsgs	listing 1	(jan)	sh.c	1029
execute	listing 1	(jan)	sh.c	631
exp_dir	listing 1	(jan)	sh.c	479
exp_vars	listing 1	(jan)	sh.c	706
file_input	listing 1	(jan)	sh.c	305
find_first	listing 7	(mar)	dir.c	45
find_next	listing 7	(mar)	dir.c	67
findvar	listing 3	(feb)	var.c	43
fixup_name	listing 7	(mar)	dir.c	137

(Continued on page 20)

Table 2: *Cross-reference for all shell-related subroutines and subroutine-like macros*

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(Continued from page 18)

: <*num*> part of the declarations, so your structures will be a little larger, but the program will still compile without modification.

The subroutines are organized functionally rather than alphabetically. You can use the cross-reference if you need to find something. The biggest potential organizational problem is sh.c (Listing One), which is too big for me to be totally comfortable with it. Break it up if you need to. The routines on lines 1137–1379 (the various system-level command support routines: *setenv*, *set*, and so on) could be made into another independent module without too much trouble, but that only gets rid of a few hundred lines.

Shell Organization

The shell itself (Listing One) is organized functionally into several parts:

- *Typedefs*, *#defines*, and so on (lines 110–2226)
- Input routines (lines 227–346)
- Command processing (lines 347–1026)
- Start-up routines (lines 1029–1136)
- Internally implemented commands (lines 1138–1378)
- The command processor itself (including main, lines 1382–1545)

Of these, the organization of the input routines needs some comment. I eventually intend to augment *Sh* with several of the loop control functions supported in the Unix C shell. The easiest way to do this is to treat the shell as a small compiler (or interpreter). That is, it's nice to have a token recognizer parse keywords from the input and then tell the command interpreter what to do rather than have the command interpreter itself figuring out what's on the input line. So, the command interpreter (*cmds( )* on line 1417) calls *next_cmd( )* to get a command from input. *Cmds( )* then strips the first word from the input line and calls *tokenize( )* to analyze this word. *Tokenize( )* returns a unique integral value that can be used to vector into a switch.

Input can come from one of three places, depending on the command line with which the shell was in-

gcur	listing 4	(dec)	vidbios.c	82
get_hist	listing 2	(feb)	hist.c	97
get_hnum	listing 2	(feb)	hist.c	188
getcur	listing 4	(dec)	vidbios.c	105
getkey	listing 5	(dec)	efgets.c	69
getl	listing 5	(dec)	efgets.c	372
getpage	listing 4	(dec)	vidbios.c	36
getvar	listing 3	(feb)	var.c	194
has_only	listing 7	(mar)	dir.c	113
has_wild	listing 1	(jan)	sh.c	348
haswild	listing 7	(mar)	dir.c	84
hist_name	listing 2	(feb)	hist.c	214
history	listing 2	(feb)	hist.c	269
interactive_ . . .	listing 1	(jan)	sh.c	269
isalias	listing 3	(feb)	var.c	25
isname	listing 3	(feb)	var.c	24
isrootdir	listing 7	(mar)	dir.c	97
ISVAR	listing 1	(jan)	sh.c	179
iswhite	listing 1	(dec)	next.c	5
ISWHITE	listing 1	(jan)	sh.c	177
main	listing 1	(jan)	sh.c	1489
mk_dir	listing 7	(mar)	dir.c	385
next	listing 1	(dec)	next.c	8
next_cmd	listing 1	(jan)	sh.c	965
nextarg	listing 1	(jan)	sh.c	441
nextarg	listing 8	(mar)	reargv.c	12
PMODE	listing 1	(jan)	sh.c	186
print_hist	listing 2	(feb)	hist.c	195
printalias	listing 3	(feb)	var.c	173
printvars	listing 3	(feb)	var.c	183
prompt	listing 1	(jan)	sh.c	858
PSTR	listing 1	(jan)	sh.c	160
ptail	listing 5	(dec)	efgets.c	112
pwd	listing 1	(jan)	sh.c	1251
rcopy	listing 1	(jan)	sh.c	915
reargv	listing 8	(mar)	reargv.c	46
reset_fileinput	listing 1	(jan)	sh.c	238
restore_hist	listing 2	(feb)	hist.c	253
save_hist	listing 2	(feb)	hist.c	231
scur	listing 4	(dec)	vidbios.c	68
search	listing 1	(jan)	sh.c	573
set	listing 1	(jan)	sh.c	1172
setargs	listing 1	(jan)	sh.c	1063
setcur	listing 4	(dec)	vidbios.c	100
setenv	listing 1	(jan)	sh.c	1138
setvar	listing 3	(feb)	var.c	137
shift	listing 1	(jan)	sh.c	1344
skipto	listing 6	(mar)	skipto.c	1
SKIPWHITE	listing 1	(jan)	sh.c	178
ssort	listing 9	(mar)	ssort.c	9
strip	listing 1	(jan)	sh.c	363
strsave	listing 5	(feb)	strsave.c	6
tokenize	listing 1	(jan)	sh.c	1393
TRACE	listing 1	(jan)	sh.c	150
unalias	listing 1	(jan)	sh.c	1227
unargv	listing 4	(feb)	unargv.c	7
unsetvar	listing 3	(feb)	var.c	62
usage	listing 1	(jan)	sh.c	1047
use_exit	listing 1	(jan)	sh.c	1382
varcpy	listing 3	(feb)	var.c	101
wchar	listing 4	(dec)	vidbios.c	112
wstr	listing 4	(dec)	vidbios.c	125

Table 2 (cont.): *Cross-reference for all shell-related subroutines and subroutine-like macros*

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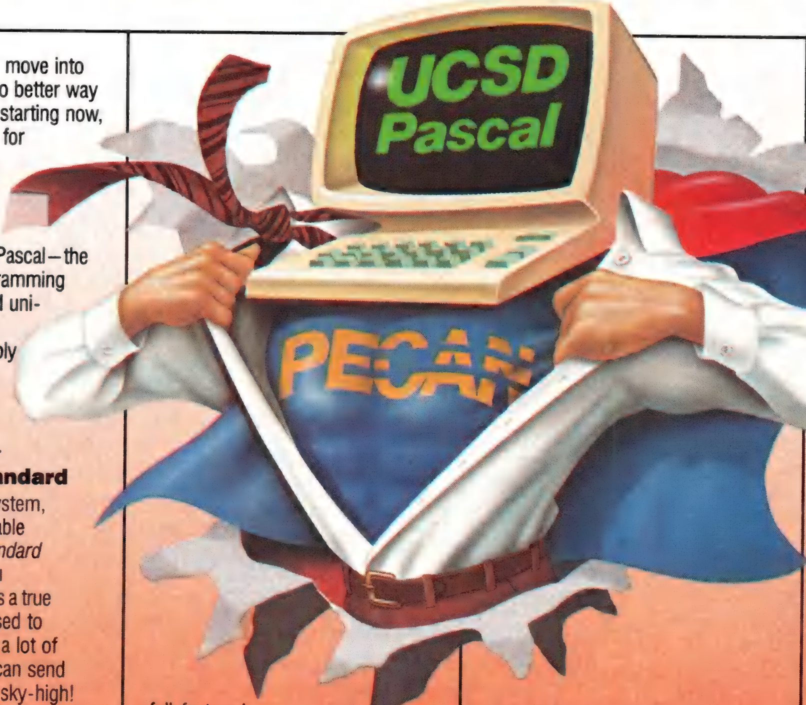

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C CHEST

(Continued from page 20)

voked: the command line itself, a file, or interactively from standard input. All three of these sources have their own problems, and I didn't want *next_cmd( )* to have to worry about these problems. Thus, the shell uses multiple input routines.

When *argv* is parsed (by *doargs( )*, line 1100), a global pointer to a subroutine (*Ifunct*, line 234) is initialized to point at an appropriate input routine. Text is then input indirectly through this pointer. *Ifunct* will point at one of the routines *interactive_input( )*, *command_input( )*, or *file_input( )*. All three routines act in the same way—they get a line of input from somewhere and put that line into the global array *Ibuf* (declared on line 216). A pointer to *Ibuf* is returned on success, and 0 is returned on EOF. The string input routine *command_input( )*, returns EOF when it reaches the end of a string to maintain compatibility with the other routines.

Of the three input routines, the weirdest is *file_input( )* (used to process batch files). The problem here is caused by collusion between MS DOS and the compiler's I/O library. When a program spawns a child process, the child inherits the parent's file descriptors. This is documented in several places, both in the MS DOS and the Microsoft C Compiler documentation. None of these sources, however, deign to mention that when the child process terminates, *exit( )* will close all open files, including those files that belong to the parent process. In other words, spawning a child process under MS DOS closes all open files in the parent process as an undesirable side effect. This problem is circumvented in *file_input( )*, which reads a line from a file, remembers the current position in the file with an *fseek( )* call, and then closes the file. The next time *file_input( )* is called, it reopens the file, seeks to the previous position in the file, and then reads another line. I know this is a kludge, but I couldn't think of any easy way around the problem short of reading the entire batch file into a local buffer and then processing that buffer. The repeated seeks seemed a better solution, but it's not a good one.

Another somewhat convoluted piece of code is the routine that does alias expansion. The expansion of a single alias is straightforward. The same routines (and tables) are used to hold and expand both aliases and shell variables. An alias has the high bit of the first character of the name set when it is stored and a shell variable does not so that the alias expansion routines can differentiate between them. That is, aliases and shell variables do not share the same name pool, even though they're stored in the same table. All the simple alias maintenance routines are in Listing Three.

The shell, on the other hand, uses the simple alias expansion routines in complex ways. The problem here is compound commands—single aliases consisting of several, semicolon-delimited commands concatenated together. These additional commands could also be aliases.

The initial command is read in by *next_cmd( )* on line 991. Blank lines and comment lines (those with a # in the far left column) are skipped at this level. Then history is applied. (Note that applying history here means that the *!* that signifies a history expansion has to be the character at the left end of the line not the first character of the command, which could be anywhere on the line following a semicolon.) Now aliases are expanded by calling the recursive routine *rcopy( )* (on line 915). Each recursive iteration expands one alias. Looking at the code as I write this, the method used seems needlessly convoluted. On the other hand, it works—"If it ain't broke, don't fix it."

Availability

This column is part of a four-part series describing the entire shell. A reprint of all four parts along with a disk containing the listings and an executable version of the shell is available for $29.95 from *Dr. Dobb's Journal*, 2464 Embarcadero Way, Palo Alto, CA 94303. Please direct inquiries to the The Shell. Prepayment is required. **DDJ**

(Listings begin on page 66)

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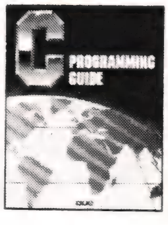

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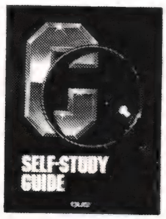

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The Great CRC Mystery

by Terry Ritter

Some implementations of XMODEM use a CRC algorithm that introduces unnecessary delay in data transmission. CRCs can be used in communications, startup verification of ROM code, and program and data correctness validation.

The Cyclic Redundancy Check (or CRC) is a way to detect errors in data storage or transmission. With more and more data being transmitted over phone lines, the need for protocols that protect data from damage in transit has increased, but the theory behind CRC generation is not well known.

What Is a CRC?

The Cyclic Redundancy Checs a way to detect small changes in blocks of data. Error detection is especially important when computer programs are transmitted or stored because an error of even one bit (perhaps out of hundreds of thousands) is often sufficient to make a program faulty. Although a few errors in a text file might be acceptable (because the text can be reedited when received or recovered), an error-free file is preferable. An error-correcting protocol triggered by CRC error detection can provide this accuracy at low cost.

The CRC algorithm operates on a block of data as a unit.[1] We can understand the CRC better if we see this block of data as a single (large) numerical value. The CRC algorithm divides this large value by a magic number (the CRC polynomial or generator polynomial), leaving the remainder, which is our CRC result.

The CRC result can be sent or stored along with the original data. When the data is received (or recovered from storage), the CRC algorithm can be reapplied and the latest result compared to the original result. If an error has occurred, we will probably get a different CRC result. Most uses of the CRC do not attempt to classify or locate the error (or errors) but simply arrange to repeat the data operation until no errors are detected.

Using the CRC

The IBM 8-inch floppy disk specification used the CRC-CCITT polynomial for error detection, and this CRC is now used in almost all floppy disk controller devices. A disk controller computes a CRC as it writes a disk sector, and then it appends that CRC to the data. When the data is read back, a new CRC is computed from the recovered data and compared to the original CRC(M If the CRC values differ, an error has occurred and the operation is repeated. The standard disk CRC (CRC-CCITT) is hidden in the controller and nowadays receives little comment.

One version of the XMODEM (or Christensen) file transmission protocol also uses the CRC-CCITT polynomial to detect data transmission errors typically caused by line noise. When the receiving end detects a data error, it sends a NAK (Negative Acknowledge) character to the sender, which requests that the defective data block be retransmitted. The receiving end repeats this process un-

til the CRC from the transmitting end matches the local result or until one or both ends give up. When the result does match, the receiving end sends an ACK (acknowledge) character, and the transmitting end then sends the next block.

Error Control and Efficiency

Many different CRC polynomials are possible; these generator polynomials are designed and constructed to have desirable error-detection properties. If the CRC polynomials are well constructed, the major difference between them is in their length. Longer polynomials provide more assurance of data accuracy and are fully usable over larger amounts of data; however, longer polynomials produce longer remainder values, adding error-checking overhead to the data.

A "16-bit" polynomial has a 16-bit remainder. There are two well-known 16-bit polynomials: CRC-16 (used in early BISYNC protocols) and CRC-CCITT (used in disk storage, SDLC, and XMODEM CRC). Of the two, CRC-CCITT may be a little stronger and by convention is often used in ways that strengthen its error-detection capabilities. This article illustrates CRC-CCITT, which is the pnomial $x^{16} + x^{12} + x^5 + 1$.

Polynomials are classified by their highest nonzero digit (or place), which is termed the degree of the polynomial. Both CRC-16 and CRC-CCITT are of degree 16, which means that bits 16 through 0 are significant in their description; a degree-16 polynomial thus has 17 bits. Normally we are most concerned with the remainder of the CRC operation, which has one bit less than the polynomial. Thus, we may think of 16-bit CRCs, even though their generator polynomials actually contain 17 bits (bits 16 through 0).

In a proper CRC polynomial, both the most significant bit (MSb) and least significant bit (LSb) are always a 1. Because the highest bit of the polynomial is always a 1, we are able to treat this bit differently from the other bits of the polynomial. Because the remainder from a sixteenth-degree polynomial has only 16 bits, a 16-bit register is sufficient for CRC operations on a 16-bit polynomial, even though the polynomial itself actually has 17 bits.

A well-constructed CRC polynomial over limited-size data blocks will detect any contiguous burst of errors shorter than the polynomial, any odd number of errors throughout the block, any 2 bit errors anywhere in the block, and most other cases of any number of errors anywhere in the data.[2] So every possible arrangement of 1, 2, or 3 bit errors will be detected. Nevertheless, there remains a small possibility that some errors will not be detected. This happens when the pattern of the errors results in a new value that, when divided, produces exactly the same remainder as the correct block. With a properly constructed 16-bit CRC, an average of one error pattern will not be detected for every 65,535 that would be detected. That is, with CRC-CCITT, we can detect 99.998 percent of all possible errors.[3]

There is no technique we can use to absolutely guarantee detection of any error, but we can minimize undetected errors at reasonable cost. Other error-detection techniques are available, such as checksum or voting, but these have poorer error-detection capabilities. For example, the single-byte checksum (used in the original version of XMODEM) appears to be about 99.29 percent accurate,[4] which seems pretty good. But for a single additional byte, the CRC technique is about 460 times less likely to let an error pass undetected. In practice, the difference is much greater because the CRC will detect all cases of the most common errors at the cost of a 2-byte CRC value in every block. For example, the XMODEM protocol sends data in 128-byte blocks; these blocks can be CRC error-checked with an additional 2 bytes—an error-check overhead of about 1.5 percent.[5]

Polynomial Arithmetic

The CRC performs its magic using polynomial modulo two arithmetic. Polynomial arithmetic mod 2 allows an efficient implementation of a form of division that is fast, easy to implement, and sufficient for the purposes of error detection. (This scheme is not particularly useful for the division of common numbers.) Polynomial arithmetic mod 2 differs slightly from normal computer arithmetic, and it is generally the most confusing part of the CRC.

A polynomial is a value expressed in a particular algebraic form, that of

$$A_n {}^*X^n + A_{n-1} {}^*X^{n-1} + \ldots + A_1 {}^*X + A_0$$

Our common number system is an implied polynomial of base 10: Each digit means the value of that digit is multiplied by the associated power of 10. The base 2 or binary system of numeration is another form of the general polynomial concept. When we see a number, we think of it as a single value; we mentally perform the polynomial evaluation in the assumed base to get a single result. On the other hand, formal polynomials are considered to be a list of multiple separate units, and the existence or evaluation of an ultimate single value for the polynomial may not be important.

Because decimal arithmetic uses constant-base polynomials, all of us already know how to do polynomial arithmetic in a constant base (10); however, the polynomials used in CRC calculations are polynomials modulo two. By modulo two we mean that a digit can have only values 0 and 1. Of course, this is always the case with binary values, so you might well wonder what all the mumbo jumbo is about. The difference is this: A modulo polynomial has no carry operation between places;[6] each place is computed separately. We perform mod 2 operations logically, bit by bit; in mod 2, the addition operation is a logical exclusive-OR of the values, and mod 2 subtraction is exactly the same (exclusive-OR) operation.

Modulo arithmetic is used for CRCs because of its simplicity: Modulo arithmetic does not require carry or borrow operations. In computing hardware, the carry circuitry is a major part of arithmetic computation and is a major contributor to speed limitations. Of course, because we have both subtraction and exclusive-OR instructions available in most computer instruction sets, this advantage is less important for software implementations of CRC. Nevertheless, the simplicity of modulo arithmetic allows several different software approaches not available in conventional arithmetic. Note that the modulo-type operations available in programming lan-

(Continued from page 27)

guages (e.g., the Pascal MOD operator) operate on entire numbers rather than individual bits or places.

A polynomial division mod 2 is very similar to common binary division, except that we perform a logical exclusive-OR operation instead of an arithmetic subtraction. Similarly, because "greater than" and "less than" are meaningless in modulo arithmetic, we can replace these operators by performing the exclusive-OR operation if the high bit is set or 1, driving the high part of the dividend to zeros.

We can implement a polynomial division as follows: A polynomial division register of a length corresponding to the remainder produced by the polynomial to be used is set up (see Figure 1, below).[7] Each element of the register should be able to hold the maximum modulo value; in mod 2, a single bit suffices. (Note that the hardware diagrams are intended only as examples. Very short CRCs are of limited practical use, and there are better ways to do the job.)

The register is cleared, then the data is shifted into the register from the right; each shift is a polynomial multiplication. Each shift also shifts a bit out of the register from the most significant bit (MSb). We know that the register value will exceed our representation when the shifted-out bit is logical 1, so we arrange to perform our polynomial subtraction when this happens; that is, when we shift out a 1, we exclusive-OR the polynomial with the value in the register. Because our polynomial (the magic number) always contains a high-order bit, which always forces the shifted-out bit back to a logical 0, we need not actually operate on the high-order bit. So only zeros shift out, keeping the mod 2 polynomial remainder in the register.

This bit-level hardware process is easily simulated. Turbo Pascal algorithms for the simulation are shown in Listing One, page 76. Software simulation has the advantage of a fast and easy investigation of an algorithm, allowing quick changes to try out various forms of optimization. The program produces a "trace" of the execution, showing the step-by-step operation.

The polynomial division register does not hold the desired remainder until the place containing the last data bit has been shifted out of the register. To do this, a zero data bit must be shifted in for every bit of the register. In the case of CRC-CCITT, 16 bits (2 bytes) of zeros need to be appended to the data. After entering the zero bits, the result in the polynomial division register is the CRC result. The common implementations of XMODEM usually require these two trailing bytes.

The CRC result can be obtained without shifting in the two zero bytes by rearranging the CRC register and feeding the data in at the "top end" of the system (see Figure 2, below). By shifting the CRC register, we can shift zeros in from the right. The data bit will be compared to the MSb in the CRC register, and only if they differ will the polynomial be subtracted. As before, this acts to keep the full remainder in the register; however, the remainder is now correct after each bit and requires no trailing zeros. A simulatioof this immediate-result algorithm (called, for lack of a better name, the CRC algorithm) is also given in Listing One for comparison to polynomial division. Notice that both the polynomial division and CRC algorithms come up with the same remainder (or CRC value), but the CRC version does it faster and with more consistent logic.

Faster CRCs in Software

The bit-by-bit form of the CRC algorithm can be, and often is, directly simulated in software. The shifting and looping required by this approach can be reduced in several ways. Both byte-oriented[8] and table-oriented[9] algorithms have been available in the technical literature for a number of years. Table-oriented algorithms may (or may not) produce somewhat higher speed at the ex-

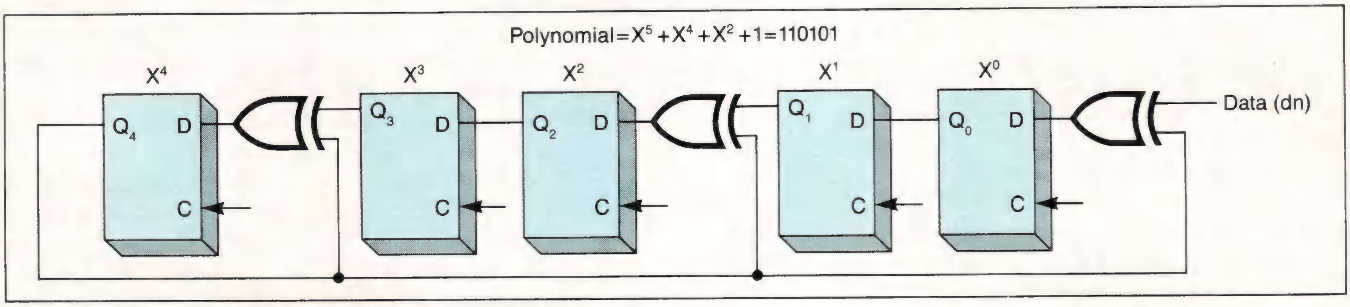

Figure 1: *Polynomial Divide Hardware for a 4 bit CRC*

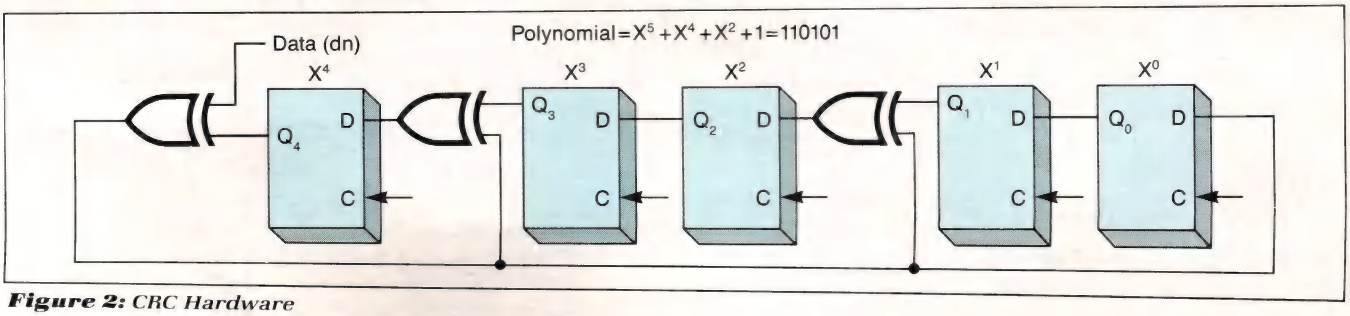

Figure 2: *CRC Hardware*

(Continued from page 28)

pense of a sizable table of constants that generally must be intialized before use. Examples of the various forms of CRC algorithms are given in Listing Two (page 78).

We can speed up the algorithm even more by precomputing the CRC for all possible combinations of a 16-bit CRC and a data byte and then saving the results. Done naively, this would be a transformation of 24 bits (16 bits of the previous register and 8 bits of data) into 16 bits. This approach would thus require 2^{25} bytes (about 34 megabytes) of lookup table. In order to make the table approach practical, we must find a way to reduce the size of the table.

If we examine the CRC hardware, we notice that the current data bit is always combined with the current MSb of the CRC register. When we compute a whole-byte CRC, we end up combining the whole data byte with the high byte of the CRC. We can precompute the exclusive-OR of the data byte and the high byte of the CRC register (this is a single-byte operation in software), yielding a single byte we can call the combined term or the combination value.

For the common 16-bit CRCs, it turns out that the CRC register changes in patterns that have a direct mapping from the combination value. Thus, it is possible to precompute the CRC changes for all 256 possible combination values. Then, when we need to do a CRC, we can use the 1-byte combination value to look up a corresponding 2-byte result, then use that result to correctly change the CRC register. As you might expect, the required change is simply a 2-byte exclusive-OR operation.

To generate the data for the lookup table, we need only generate the 2-byte CRC result for all 256 possible data bytes, given an "all-zeros" starting CRC register. Each result is a 1 for those bits in the CRC register that are changed by a particular combination code. We can use a nontable implementation of the CRC to compute the table values.

This approach to generating a table of CRC values requires a 512-byte lookup table. We must fill the table with the correct data in an initialization step and perform a few more run-time operations than the straight lookup process requires (compute the combination value, look up the result, then apply the result to the CRC register and compute the new CRC value).

Another variation that is faster than the original bit-by-bit approach and that also eliminates the lookup storage of the table approach is the bytewide shifting algorithm. A bytewide approach eliminates seven bit-by-bit test-and-jump operations, which are a significant overhead in the bit-by-bit version, and also takes advantage of fast-shift and parallel-logic operations available on most processors (as well as some high-level languages such as Turbo Pascal or C).

First, we need some more algebra: By giving each CRC register bit and each data bit a separate symbol, we can express the result of a CRC operation symbolically. Each bit of the CRC register will be represented by a formula showing all the data and original CRC bits that affect that bit in the result. If we take the exclusive-OR of the bits specified by the formula, we can directly calculate any bit of the CRC result.

In order to generate the formulas for each bit of the CRC register, we create an algebraic analog of the shifting and combining process of the bit-by-bit CRC algorithm. Instead of shifting bit values (as in a normal shift register), we move the whole symbolic formula for each bit to the next higher bit position. Instead of actually performing an exclusive-OR operation, we concatenate the formula for the data bit to each of the affected bits in the CRC register with a symbol indicating an exclusive-OR operation. If ever we find two identical variables in any one formula, we can cancel and eliminate them both (because anything exclusive-ORed with itself is zero, and zero exclusive-ORed with any value is just that value).

After symbolically processing a whole byte of data and eliminating common terms, we come up with a symbolic representation for each bit of the result. By factoring this expression into convenient computer operations, a program is obtained that uses the bit parallelism available in software.

CRC Deviations

More improvement is possible. We have previously assumed that the CRC register is cleared before starting the computation and also that we specifically compare the stored (or transmitted) CRC value to the current CRC result. These assumptions are discarded in protocols other than XMODEM.[10]

When a CRC register contains only zeros, processing a zero data bit does not change the CRC remainder. So, if the CRC register is clear and extraneous zero bits do occur, these data errors will not be detected. For this reason, most current CRC protocols initialize the CRC register to all 1s before they start the computation, allowing the detection of extraneous leading zeros.

We can also eliminate the need to detect the separate CRC field at the end of a data block. If the CRC result is simply attached to the end of the data, the receiving CRC register will clear itself automatically if there is no error; that is, each bit of the stored or transmitted CRC value should cancel the similar bit in the CRC register. Although of minor importance for software implementations, this is a reasonable simplification for hardware CRC devices because it allows the same hardware to be used regardless of block length.

When the CRC remainder is appended to the end of the data (thus eliminating the need to detect it as a separate field), and if bit-level CRC hardware is also to be supported, CRC software may need to use data in reverse bit order. This is because bit-level CRC hardware works on data after it has been serialized, and data is traditionally serialized LSb-first. That is, the parallel-to-serial conversion in an asynchronous serial device sends the rightmost bit of a character first and the leftmost bit last. The bit-level CRC hardware has little choice but to treat the resulting data-stream as a single large number, but that data-stream has its byte-level bit-order changed from our usual numerical expectations.

If an MSb-leftmost CRC routine is to be compatible with bit-level CRC hardware, it may be necessary to reverse the bit order of every data byte (before each is processed

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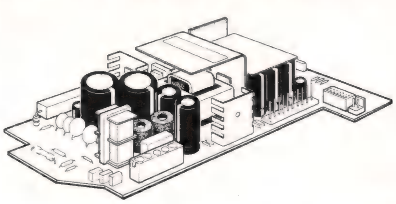

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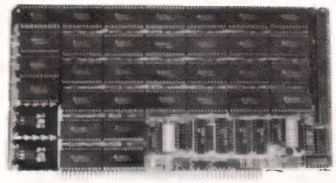

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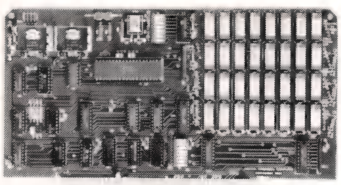

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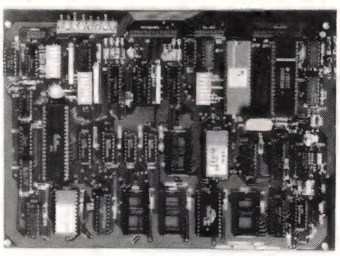

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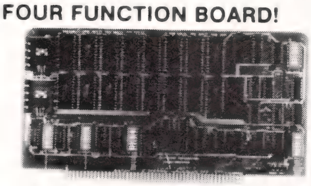

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CRC

(Continued from page 30)

or serialized) and also the CRC remainder bytes (after the block ends). Bit-order reversal can be done in software, hardware, or both. Alternately, the CRC algorithm could be reconstructed so as to use and hold MSb-rightmost data.

In strictly software CRC implementations, however, we work on data before it is serialized and after it is recovered, and we trust any serialization that occurs to be transparent. We can t afford to treat the data-stream as a single large value with MSb-leftmost, with MSb-leftmost bytes, and a similar MSb-leftmost CRC remainder appended on the right. This arrangement is most consistent with both the theory and our numerical conventions and is the form used by XMODEM. The CRC routines shown in this article use MSb-leftmost data and keep the result also in MSb-leftmost format.

If we arrange to verify the CRC by processing the CRC result as data, we again fall prey to extraneous zero data bits. In order to detect such errors, we arrange for the CRC register to take on a unique nonzero value in the event of no error. By some quirk of the algebra, it turns out that if we transmit the complement of the CRC result and then CRC-process that as data upon reception, the CRC register will contain a unique nonzero value depending only upon the CRC polynomial (and the occurrence of no errors). This scheme is now used by most CRC protocols, and the magic remainder for CRC-CCITT is *$1D0F* (hex).

```
CRCTIME, 85/9/18
Execution times for various CRC implementations.
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BEGIN Validation Testing.
    Reference = crcittby (Pascal Bit-By-Bit).
    crcfbbb (Pascal Fast Bit-By-Bit): No error.
    crcitta (Pascal Byte): No error.
    crctablu (Pascal Table): No error.
    mcrcitt1 (Machine Code Byte): No error.
    mcrcitt3 (Machine Code Table): No error.
END Validation Testing.

Turbo Pascal runs CRC-CCITT on 8088 under Bare MSDOS
    FOR 10000 OPERATIONS; 7.16 MHz CLOCK (multiply by 1.5
        for 4.77 MHz)

Empty loop: 0.160 secs
Empty procedure in loop: 0.880 secs
    (procedure overhead alone = 0.072 msec each)
```

	10,000 Uses (secs)		1 Use (msec)	
	Procedure	In Line	Procedure	In Line
Pascal Bit-by-Bit:	13.790	13.070	1.379	1.307
Pascal Fast B-B-B:	7.310	6.590	0.731	0.659
Pascal Byte:	2.150	1.430	0.215	0.143
Pascal Table:	1.430	0.710	0.143	0.071
Machine Code Byte:	1.050	0.330	0.105	0.033
Machine Code Table:	0.890	0.170	0.089	0.017

Table 1

Actual CRC Implementations

I constructed several CRC implementations for speed and size comparisons (see Listing Two). The CRC-CCITT polynomial was used because this is the polynomial used in XMODEM, as well as many other data communication uses. I used Turbo Pascal, though the code could obviously be rewritten in C. A couple of the operations used are Turbo Pascal extensions: *Swap( )* is an INTEGER function that exchanges the high and low byte of an integer value; *Lo( )* is an INTEGER function that selects only the low byte of an integer.

I used the Pascal Bit-by-Bit approach (a direct simulation of the hardware method) to provide a reference against which the other algorithms are compared. The Pascal Fast B-B-B is an improved bit form comparable to most high-level language implementations of the XMODEM CRC, except that this version requires no trailing zeros to finish the calculation (and so is already faster than the usual version). The Pascal Byte version illustrates the improvement wrought from algebraic factoring; the Pascal Table version shows how a precomputed table can simplify and speed execution-time operation. The Machine Code versions of Byte and Table show yet more improved speed. The different approaches illustrate various trade-offs of speed, space, and specialization. The results (Table 1, left) show a range of almost two orders of magnitude in execution speed.

Each CRC implementation was made into a Pascal PROCEDURE for easy testing and comparison. For validation, varying amounts of program code from main memory were processed by each implementation. All algorithms achieved the same results. Several of these versions have been placed in an implementation of XMODEM with good results.

Time Tests

For the time tests, each implementation was executed 10,000 times under Turbo Pascal 3.01A on an 8088 in a Leading Edge PC with a 7.16-megahertz (MHz) clock; the times would be 50 percent longer on an IBM PC. The time was taken automatically from MS DOS. Because the MS DOS timer ticks only about 18.2 times per second, this method is only precise within about 55 milliseconds (msec) at both the start and end of the timing interval. The large number of repetitions minimize this effect.

The time reported as "10,000 uses" is real time decreased by the amount of time taken by 10,000 empty loops, thus giving us the time associated with the procedure call and execution instead of also including the looping structure that we use only for the tests. The In Line column decreases "10,000 uses" by the time taken for 10,000 procedure calls and returns, giving the time for execution only.

Selection Criteria

The time necessary to process a byte (including the CRC operation and whatever queuing operations and other tests that need to be performed) should be less than the

CRC

(Continued from page 32)

time it takes to receive a character. We could simply accumulate the data in a block as it is received and then CRC-process the whole block, but this procedure would add some delay, or latency, between receiving the last data byte and returning a response to the sender (ACK for good data and NAK for an error in XMODEM). Some XMODEM implementations appear to use this method, giving the impression that the protocol or the CRC is responsible for the delay. Because fast CRC routines are obviously possible, it is hard to rationalize any latency at all.[11]

The Pascal Byte version, which takes only a few lines of code and is machine independent (under Turbo Pascal), may be suitable for speeds up to 9,600 bps and is a reasonable choice for most use. The Pascal Table version is a little faster, but the table generally must be initialized before use, either by using a different CRC version, or perhaps by reading the values in from a file. Alternately, (in most languages) the table could be defined in the source code as a large body of constants.

The faster versions can generally benefit from being used in-line (that is, not as procedures) to avoid procedure call/return overhead, but this is also inconvenient because each use would involve duplicating the same code in different places. The Machine Code Table version is shorter and so would minimize the duplication penalty. The Pascal Table version can also be used in-line because it takes a minimum amount of code. I use an Include file holding the Machine Code Byte version, then call the routine as a procedure; the resulting code is both small and fast.

Other Uses

Although this article has concentrated on CRCs in communications and data storage, CRCs can be used in many different applications involving error detection. Such applications include start-up verification of ROM code, load-time verification of RAM modules (as in the 6809 operating system OS9), and program and data correctness validation.

Note that CRC polynomials are designed and constructed for use over data blocks of limited size; larger amounts of data will invalidate some of the expected properties (such as the guarantee of detecting any 2-bit errors). For 16-bit polynomials, the maximum designed data length is generally $2^{15}-1$ bits, which is just one bit less than 4K bytes. Consequently, a 16-bit polynomial is probably not the best choice to produce a single result representing an entire file or even to verify a single EPROM device (which is now commonly 8K or more). For this reason, the OS9 polynomial is 24 bits long.

How To Learn More

A good introduction to CRCs can be found in the classic *Error Correcting Codes*, 2d ed., by Peterson and Weldon (Cambridge, Mass.: MIT Press, 1972), but you can expect to do some serious math to understand it. A brief nonmathematical chapter on CRC error detection in data applications (with some good figures) is available in *Technical Aspects of Data Communication*, 2d ed., by J. McNamara (Digital Equipment Corporation: Digital Press, 1982). The very brief section in *Computer Networks* by A. Tanenbaum is also fairly good.

Notes

1. The CRC does not require a fixed block size (though there is a built-in maximum), but some error-correcting protocols do. Larger amounts of data are simply partitioned into blocks that are considered separately.
2. Peterson, W. W., and Brown, D. T. "Cyclic Codes for Error Detection." *Proceedings of the IRE* (January 1961): 228–35.
3. Tanenbaum, A. *Computer Networks*. 128–32. Englewood Cliffs, N.J.: Prentice-Hall, 1981.
4. Brooks, L., and Rasp, J. "How Accurate is Accurate?" *DDJ* (February 1984): 27.
5. Error detection is only part of the requirements for a protocol. Other requirements include transmitting the data in blocks, numbering the blocks, and responding when a block has been received. The corresponding design decisions in XMODEM typically add yet another four bytes to each block transferred, for a required overhead of about 4.5 percent. This value can be, and often is, additionally degraded in implementation.
6. The general case of polynomial arithmetic, which allows a nonconstant base, generally makes carry operations (between terms) difficult.
7. It is common and traditional for the CRC register to be shown shifting right, which is the exact reverse of this author's analogy to binary division. Given our system of numeration, it seems reasonable to place most significant digits of one value to the left, and it is then correct for the CRC register to be seen as shifting to the left.
8. Helness, K. "Implementation of a Parallel Cyclic Redundancy Check Generator." *Computer Design* (March 1974): 91–96; Vasa, S. "Calculating an Error-Checking Character in Software." *Computer Design* (May 1976): 190–92; Socha, H., et al. "Letter to the editor." *Computer Design* (May 1979): 6, 12; Kjelberg, I. "Letter to the editor." *IEEE Micro* (August 1985): 4, 99.
9. Whiting, J. "An Efficient Software Method for Implementing Polynomial Error Detection Codes." *Computer Design* (March 1975): 73–77; Perez, A. "Byte-wise CRC Calculations." *IEEE Micro* (June 1983): 40–50; Schwaderer, D. "CRC Calculation." *PC Tech Journal* (April 1985): 118–32.
10. McKee, H. "Improved CRC Technique Detects Erroneous Leading and Trailing 0's in Transmitted Data Blocks." *Computer Design* (October 1975): 102–6; Fortune, P. "Two-Step Procedure Improves CRC Mechanism." *Computer Design* (November 1977): 116–29.
11. Some protocols other than XMODEM allow subsequent blocks to be sent before a previous block is acknowledged, thus minimizing the latency problem.

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(Listings begin on page 76)

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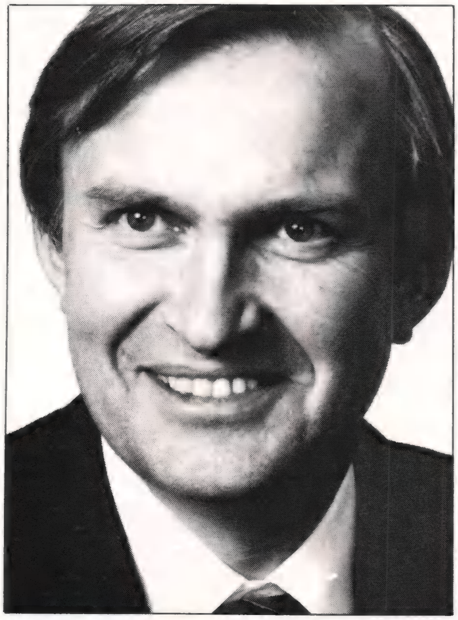

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Fast Integer Powers for Pascal

by Dennis E. Hamilton

The function introduces the fastest method for computation of $x^{**}n$. This decade has seen renewed interest in computation of powers.

Because the Pascal language does not provide any built-in operation (such as FORTRAN's *x**n*) for powers of numbers, programmers are led to try the costly and unreliable substitute *exp(n*ln(x))*. When *n* is an integer, however, there are often ways to factor out computation of powers altogether. When direct use of powers is still desirable, the Pascal function *PowerN(x, n)* introduces the fastest method known for general computation of *x**n* for *n*, an unrestricted integer not known in advance.

Increasing Use of Powers

Repetitive computation of powers of numbers is almost commonplace now that personal computers and software make elaborate arithmetic computations more affordable and easier to express.

Powers do not occur merely in the evaluations of polynomials and the summations of series for computing specialized mathematical functions. Powers (especially ones with variable exponents) occur routinely in work with statistics and probabilities and in financial and economic formulas.

Typically, the exponent is an exact integer, opening up the possibility of using special shortcuts for faster and more accurate computation. The Pascal *PowerN* function introduced in this article uses just such shortcuts to implement the fastest general computation known.

PowerN is extremely efficient on systems, including most microcomputers, where floating-point arithmetic is more costly than small-integer hardware operations. Use of *PowerN* is also almost always preferable to use of the questionable *exp(n*ln(x))* logarithmic method. (See sources 1; 7; 15; 11, Section 4.6.4 for even better possibilities.)

Powers Defined

For integer exponent value, *n*, the *n*th power of the base value *x* is designated here by the notation *x**n* originally popularized in FORTRAN. These powers are usefully understood in terms of repeated-multiplication operations according to the scheme proposed in 1676 by Isaac Newton:

```
x**n = x*x* . . . *x,          n > 0
       <- n x's ->
     = 1,              n = 0 and x <> 0
     = 1/x**(-n),      n < 0 and x <> 0
```

This formulation of *x**n* (and the mathematician's x^n) satisfies our intuitions (for *n > 0* at any rate) and allows use of some nicely generalized "laws of exponents" for powers:

```
x**(i+j) = x**i * x**j,
       x <> 0 or (i > 0 and j > 0)
x**(i*j) = (x**i)**j,
```

The restrictions are significant: Standard mathematics defines no specific quotients for divisions by zero; it is technically important to avoid sneaking any in as loopholes of the exponent laws. With due allowance for the restrictions, satisfaction of these laws justifies the shortcuts in practical computations with variable, large *n*.

Algorithm Performance

Pascal function *PowerN(x, n)*, given in Listing One, page 84, derives *x**n* using exactly

```
MC(n) = floor(lg(n)) +
        bits1(n) - 1,        n > 0
      = 0,                   n = 0
      = MC(-n),              n < 0
```

multiplications. Here, *bits1(n)* is the number of 1-bits in the representation of *n* by a binary integer, *lg(n)* is the base 2 logarithm of *n*, and *floor(x)* is the greatest integer that isn't larger than *x*. Even the ambitious case *PowerN(x, 32767)* is computed with only 28 multiplication operations (including *sqr(x) = x*x*).

Another part of the claim to *PowerN*'s superiority, despite its superficial complexity, involves the decision cost expended in order to achieve so few multiplications. The number of questions of the form *odd(i)? i <> 1? n < 0?* that have to be asked is

```
DC(n) = MC(n) + 4,   n <> 0
```

where two are just for checking the

special $n = 0$ and $n < 0$ cases. The two extras arise when the *not odd(i)* and $i <> 1$ checks finally fail—it's time not to multiply.

PowerN also never computes anything not used in the final result. Failures (such as overflow) in intermediate computations occur only when failure is truly inescapable.

Accuracy Considerations

To confirm that *PowerN* does indeed produce expected results, I have included a Turbo Pascal driver program called TPWRN.PAS (See Listing Two, page 84.)

Using TPWRN, *7**i* is computed exactly and rapidly up to $i = 14$. Thereafter, the 39-bit effective precision (and 11-digit output rounding) are inadequate for confirming exact results with the CP/M-80 edition of Turbo Pascal.

On the other hand, comparative calculations for *(1/7)**−i*, although mathematically the same as *7**i*, deteriorate quickly. Value *1/7* cannot be carried exactly, and the discrepancy is quickly magnified in taking powers. By $i = 14$, the error exceeds *10*, even though minimal error in *7**14* has just shown up.

The final column of TPWRN output shows how much more quickly the calculus textbook approach, using *exp(i*ln(7))*, breaks down. Because this method is noticeably slower as well, there is nothing to commend it for exact-integer exponents.

In making use of these results, keep in mind that the *PowerN* vintage 1.xx algorithms are the best available in terms of providing a direct solution at minimum cost. Nevertheless, working with the same precision as the input data inevitably dooms you to some sort of error. It is wise to be mindful of the prospective errors, however insignificant you regard them to be.

PowerN Method

PowerN makes rapid computation of integer powers using the fundamental method of Donald E. Knuth's algorithm 4.6.3A (see source 11). The number of floating-point multiplications is reduced by taking advantage of the laws of exponents, in form

```
  x**2i    =  sqr(x)**i,      i > 0
x**(2i+1)  =  x**2i * x,      i > 0
```

In Knuth's formulation, as in *PowerN*, the first transformation is performed in an inner loop that doesn't stop until an odd exponent is inevitably reached. This idea is elegantly restated, at somewhat increased decision cost, by Dijkstra and Jensen and Wirth (see sources 3 and 10):

```
r := 1.0;
while i > 0
   do begin
      while not odd(i)
         do begin
            x := sqr(x);
            i  := i div 2
            end;
      r := r*x; i := i - 1;
      end;
```

The lower decision cost of *PowerN* is obtained by not checking for even *i* quite so often. This applies a suggestion of David Gries to the effect that the inner *while* can be replaced by *repeat* upon arranging that *i* always be even whenever the $i > 0$ test passes

PASCAL
(Continued from page 37)

(see source 6). The saving of decisions is comparable to what Knuth obtains from the start using *go to*.

The main new idea in *PowerN* involves using the initialization (for guaranteeing that even powers always remain) to also replace the usual *r := 1.0* and first *r := r*x* by a well-timed *r := x*.

The procedure is further optimized by using *i shr 1* in place of *i div 2* on Pascal implementations that permit it. Because *i div 2* has the effect of also decrementing odd values of *i* in the one operation, separate adjustments to *i* are unnecessary.

PowerN(x, 0) = x/x deserves special mention. It is not known what nonstandard assumptions are implemented in each computer arithmetic. If there is some provision for undefined operation *0/0*, however, you would wish to employ it. Use of *x/x* to catch *x = 0* or *x = nonstandard value* is then consistent with IEEE proposals for floating-point arithmetic (see source 2). It is also as good as any other approach, assuming consistent extension of the laws of arithmetic and exponentiation to propogate indeterminate results:

```
x**0 =     x**-0   = 1/(x**0);
x/x  =               1/(x/x);
```

or simply

```
x**0 =     x**(1-1)  = x/x.
```

PowerN is contrived to propogate all cases without knowing in advance which ones actually apply.

Availability

Current editions of POWERN.PLB (Listing One) and the TPWRN.PAS test driver are posted to the Borland International Forum (page BOR-100) on the CompuServe Information Service. Database DL1 of the forum provides ready-to-run Turbo Pascal versions.

I check onto CompuServe regularly. You can contact me via User ID 70100,271 for open discussions on either the CP/M Forum (go CPMSIG) or the Borland International Forum.

Sources

Because powers are not as elementary as the standard operations of addition, subtraction, and multiplication, they (like general division and remainder operations) still lack widely recognized standard mathematical definitions. (Despite this condition, many programming language manuals and standards continue to omit definitions for their language's implementation of powers, long after the ALGOL 60 report established the standard of precision I've tried to sustain here.)

This decade has seen renewed interest in computation of powers because the high-performance technique provides a lovely algorithmic method for generalization to several other problems. Even so, recent interest in describing computational methods for powers hasn't stabilized: Little slips are made in even the latest work, sometimes despite the existence of superior versions in older, accessible publications.

1. Cody, William J., Jr., and Waite,

William. *Software Manual for the Elementary Functions.* Englewood Cliffs, N.J.: Prentice-Hall, 1980. If computational cost and exclusion of useful cases weren't enough of an indictment of *exp(n*ln(x))* for *x**n*, there are also accuracy problems to contend with. Chapter 7 describes the considerations that apply to sustaining maximum numerical precision in the computation of powers. *PowerN* doesn't escape such problems either, as demonstrated with the TPWRN driver.

2. Cody, W. J.; Coonen, J. T.; Gay, D. M.; Hanson, K.; Hough, D.; Kahan, W.; Karpinski, R.; Palmer, J.; Ris, F. N.; Stevenson, D. "A Proposed Radix- and Word-Length-Independent Standard for Floating-Point Arithmetic." *IEEE MICRO* 4, 4 (August 1984): 86–100. See the references, too. Articles in the special issue of *IEEE Computer* 14, 3 (March 1981) provide extensive discussion of the approach adopted for IEEE floating-point arithmetic standards.

3. Dijkstra, Edsger W. *A Discipline of Programming.* Englewood Cliffs, N.J.: Prentice-Hall, 1976. The sixth small example, pp. 65–67, provides some useful insight into the fundamental fast exponentiation technique, its underlying beauty, and the pitfalls of seemingly simpler alternatives.

4. Dromey, R. G. *How to Solve it by Computer.* London: Prentice-Hall International, 1982. Chapter 1, especially Sections 1.4–1.7, is enough to commend this book as a companion to a good Pascal manual and primer. All of Chapter 3 is relevant to the methods and application of *PowerN*, although algorithm 3.7 has the "late-termination inefficiency" of an extra *sqr(x)*, just as in sources 9 and 16. The careful discussion of the method, benefits, and special applications (Problem 3.7.3) make this treatment well worth attention, however.

5. Gries, David. *The Science of Programming.* New York: Springer-Verlag, 1981. A crisp derivation of the correctness of the fundamental transformation is found on pp. 239–240. It is an useful exercise to establish that the different form of the Knuth transform and its counterpart in *PowerN* preserve all the essential conditions. (See sources 3 and 10 also.)

6. Gries, David. Personal communications. June 13, 1985 and August 14, 1985.

7. Hamming, Richard W. *Introduction to Applied Numerical Analysis.* New York: McGraw-Hill, 1971. Nowadays, more people than ever before seem to be using computation in dangerous ignorance of underlying assumptions, but the microcomputer is also a tool for demonstrating and comprehending the limitations of those very same methods. The first chapters of this book provide a good start on learning how not to surrender your fate to some printed formula.

8. Horowitz, Ellis, and Sahni, Sartaj. *Fundamentals of Computer Algorithms.* Potomac, Md.: Computer Science Press, 1978. Chapter 9 is of interest in conjunction with study of source 11, Section 4.6.4. Exercise 9–17 and the related discussion of Horner's method (pp. 424–428) make unceremonious introduction of the Dijkstra-Jensen-Wirth version as a hint for evaluation of entire (sparse) polynomials. Additional ideas are offered in Exercise 9–22.

9. Hultquist, Paul F. "The Powers That Be." *PC Tech Journal* 3, 5 (May 1985): 213–214. Here's an alternative formulation to be compared against *PowerN*'s delegation of error handling to intrinsic system actions. Although this solution is also based on Knuth's algorithm 4.6.3A, its statement in Pascal has introduced a useless but overflow-prone squaring of *x* that Knuth avoided. (See source 11, exercise 4.6.3–1.)

10. Jensen, Kathleen, and Wirth, Niklaus. *Pascal User Manual and Report.* 2d ed. New York: Springer-Verlag, 1978. See Programs 4.8 (pp. 28–29) and 11.8 (p. 81). Jensen and Wirth recognize that if the exponent is even and nonzero, it must remain nonzero until after it is divided down to an odd value. This seems to be the

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(Continued from page 39)

earliest widely published example of using a nested *while* (*PowerN: repeat*) to deftly avoid questions for which the answer is already certain. Nevertheless, Section 11 (p. 160) gives a power function that always squares the base value once too often. This pattern is sustained in the latest edition as well.

11. Knuth, Donald E. *The Art of Computer Programming.* vol. 1, *Fundamental Algorithms.* 2d ed. Reading, Mass.: Addison-Wesley, 1973. Section 1.2.2 and Exercise 1.3.1−22 provide useful background on computation of powers.

Vol. 2, *Seminumerical Algorithms.* 2d ed. Reading, Mass.: Addison-Wesley, 1981. Section 4.6.3, Evaluation of Powers, also shows where further performance can be gained when there are special cases and global usage information to exploit. Section 4.6.4, Evaluation of Polynomials, can be even more valuable, though.

PowerN's algorithm 4.6.3A heritage is now masked by the amount of reordering introduced to utilize Pascal control structures. Algorithm 4.6.3A is optimized around *odd(i)* or *i mod 2* being obtained as a byproduct of a single *i div 2* operation. This is particularly profitable when working in nonbinary representations. In contrast, *PowerN* is loaded with implicit assumptions about use of binary integers and the related efficiency of *odd(i)* and *i div 2* (or *i shr 1*) determination.

12. Knuth, D. E.; Lynch, W. C.; and Speroni, J. *Univac Solid-State Systems FORTRAN II Processor.* Univac Division of Sperry Rand, 1962. "X**J Power-Routine" update, May 20, 1963, by Dennis E. Hamilton. This use in an equivalent of BCD arithmetic approached algorithm 4.6.3A simplicity by noticing that *i* must be odd when *2*(i*5 dshr 1) <> i* and *dshr* is a decimal shift. It was also economical to detect shortcuts for *x**2 = 1* and *r = 0*. Similar tests were removed from *PowerN* because any benefit for microcomputer Pascal is doubtful compensation for the added overhead.

13. Newton, Isaac. "Letter of October 24, 1676". In *A Source Book in Mathematics, 1200−1800.* D. Struik, ed. Cambridge Mass: Harvard University Press, 1969. The common (pre-FORTRAN) notation for powers was introduced by Descartes and generalized by Newton and Leibniz [Cajori, Florian. *A History of Mathematical Notations.* vol. 1. Lasalle IL: Open Court, 1928. Sections 297−315].

14. Reynolds, John C. *The Craft of Programming.* London: Prentice-Hall International, 1981. Section 1.3.5 works carefully through several refinements just short of the Knuth formulation. In Section 4.2.5, the extraneous *sqr(x)* is avoided in a version that is rather tangled but systematically derived. There is, however, well-structured relief promised in a hint (Exercise 4.2.8−1) credited to David Gries.

15. Wirth, Niklaus. *Systematic Programming.* Englewood Cliffs, N.J.: Prentice-Hall, 1973. Chapters 1−9 provide just the sort of weaponry needed to derive modules such as *PowerN* (see Exercises 5.1−5.3) and also learn how to avoid needing *PowerN* in many cases (Chapter 9).

16. Wirth, Niklaus. *Programming in Modula-2.* 2d ed. New York: Springer-Verlag, 1983. An interesting variant on the *PowerN* method is discussed in Section 6.2 (pp. 20−23). Saving decrements in the second Power module is also at the cost of an extra squaring and possible overflow, however.

PowerN borrows the useful idea that odd *i* need not be decremented because *(2*k+1) div 2 = (2*k) div 2* anyhow. It now takes more thought to properly state the second *while* condition and accompanying loop invariants, however.

DDJ

(Listings begin on page 84)

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Learning Ada on a Micro

by Do-While Jones

A Draw Poker program provides a vehicle for presenting some features of the Defense Department's favorite language.

If you want to use the most technically advanced programming language available, you should learn Ada.

Validated Ada compilers are expensive and run on mainframe computers, but there is an affordable Ada subset that runs on CP/M-80 systems and that is complete enough to give you some useful experience. I wrote and tested all the examples in this article on a 62K CP/M system using a beta-test version of the Maranatha A compiler. A later version of this compiler is now sold under the name Supersoft A.

Ada's most attractive features show up only in large, complicated programs. Simple routines, such as sorting algorithms and finding factorials, don't demonstrate Ada well. That's why the following example is not an example of a program but is an example of a software development project.

Here's the problem. Imagine that you are starting a video-game business and that your first product is to be a Draw Poker game similar to those that are legal in Nevada.

You start off with this system requirement: The player puts as many coins in the game as he wants to bet, and it displays five playing cards. (Throughout this article, the feminine pronouns *she* and *her* always refer to Ada. The neuter pronouns *it* and *its* refer to an inanimate object, usually a computer or computer program. The masculine pronouns *he* and *his* refer to a male or female programmer or user.) The player decides to hold or discard each of the five cards. After the player has made his decision, the game displays the cards that replace those that the player has discarded and evaluates the player's hand. If the player has a winning hand, it dispenses some coins determined by the player's bet and the value of his hand.

Do-While Jones, 324 Traci Lane, Ridgecrest, CA 93555

You are probably anxious to see the final result, so let's look at the solution in Listing One, page 86, before going through the step-by-step development.

Easy to Read

Listing One contains no comments, but because Ada is so easy to read, you might be able to understand the listing even if you have never seen an Ada program before. Ada is designed to be easy to read so that any programmer (not just the program author) can quickly (and correctly) modify the program. This reduces the software support cost—a major factor in software life-cycle costs.

The program begins by opening a new deck of cards called the *STOCK*. It then begins a loop that continues as long as the player wants to place a bet. It asks the player, "How many dollars do you want to bet?" and waits for him to enter a *WAGER*. The loop repeats until the *WAGER* is zero, and then the program ends.

If the player places a bet, the program shuffles the *STOCK* and deals five cards from it to the *PLAYERS_HAND*. The *PLAYERS_HAND* is displayed, and the player has an opportunity to discard as many cards as he likes. The program then deals as many cards as are necessary to refill the *PLAYERS_HAND* and displays the *PLAYERS_HAND* again.

Next, the program computes the value of the *PLAYERS_HAND*. If it contains a *ROYAL_FLUSH*, the *PAYOFF* is 250 to 1. If the *PLAYERS_HAND* has a *STRAIGHT_FLUSH*, the *PAYOFF* is 50 to 1. The more common hands have lower returns, the lowest being *TWO_PAIR*, which has a 2 to 1 *PAYOFF*. Any other hand (including a single pair) does not pay the player anything.

If the *PAYOFF* is 0, the program prints the message "Sorry, you lose." Otherwise, it tells the player what winning combination he has and tells him how much he has won. (The player's winnings are equal to the *WAGER* multiplied by the *PAYOFF*.)

After the program has told the player how much he has won, it goes back to the top of the loop and asks him how much he wants to bet this time.

The Draw Poker program illustrates the concept of top-down programming. The main program was written from the design specification without much regard for the details of how the program will actually do what it needs to do. At this point in the design, it is not necessary to know exactly how the program will get the player's bet, figure out if he has a winning hand, and drop the right number of silver dollars. The program must do these things somehow but the details come later.

Notice that the program reads very much like the system design specification does, which makes it easy to see if it addresses all the design requirements—you simply compare the program to its specification.

An Object-Oriented Language

Draw Poker was an easy program to

(Continued from page 42)

write in Ada because Ada is an object-oriented language. The first computer languages were equation-oriented—they were designed to solve problems that involved equations. Equations of motion, equations for solving polynomials, and equations for solving matrices are well known, but what is the equation of a draw poker game? It's true that people have written programs to play card games in such equation-oriented languages as BASIC and FORTRAN, but some mental tricks were required to translate the game rules into equations and the cards into variables. Object-oriented languages let you solve the problem directly without those mental tricks—you can let your imagination run wild because you don't have to worry about practical details right away.

A Visual Solution

Here's how I imagine a card game. I see a deck of cards, called the stock. If I were imagining a bridge game, I would imagine two decks of cards, one with a red design on the back and the other with a blue design. In Ada I would express this concept as follows:

```
STOCK, RED_DECK,
                BLUE_DECK : Decks;
```

This indicates that *STOCK*, *RED_DECK*, and *BLUE_DECK* are three different objects, but they are all the same type of thing. They are all decks of cards, so I have defined them to have the type *Decks*.

Next, I remove the cellophane wrapper from a deck of cards and discard it (along with the jokers). I examine the cards and find they consist of 52 cards of 4 suits and 13 ranks, neatly sorted by suit and rank. In Ada, I can write a procedure to open a new deck of cards using the simple command

```
Open_New(STOCK);
```

The dealer picks up the stock and begins to shuffle it.

```
Shuffle(STOCK);
```

The dealer then begins dealing cards. He deals a card to you, one to me, and finally one to himself:

```
Deal_A_Card(YOUR_HAND);
Deal_A_Card(MY_HAND);
Deal_A_Card(DEALERS_HAND);
```

Again *YOUR_HAND*, *MY_HAND*, and *DEALERS_HAND* are individual objects of the same type. In order to distinguish each of these objects from decks of cards, I define them to be of type *Hands*:

```
YOUR_HAND, MY_HAND,
   DEALERS_HAND : Hands;
```

Open_New, *Shuffle*, and *Deal_A_Card* all show actions, so they act as verbs. *STOCK*, *RED_DECK*, *BLUE_DECK*, *YOUR_HAND*, *MY_HAND*, and *DEALERS_HAND* are the objects of those verbs. I need to describe those objects to Ada before I can tell it how to do the actions the verbs require.

Type Definitions

What is a deck of cards? It is a collec-

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(Continued from page 44)

tion of individual cards. In Ada, two data types—an array or a record—can represent a collection of things. An array is used to represent a group of items of the same type, while a record represents items of different types. Because of the fact that cards are all of the same type, it seems natural to use an array to represent a deck of cards:

```
type Decks is array(1 . . 52) of Cards;
```

When you try to use a deck of cards, you will find out that you need to know a little more about decks of cards, so this type definition will have to be improved, but let's let it stand as it is for a moment. It says that objects that are *Decks* have the structure of an array. This array has 52 elements, and each element is an object that has the type *Cards*. I must therefore define the data type *Cards*.

A card has two components—a suit and a rank. I can't use a two-element array because suits and ranks are not interchangeable, so they must be of different types. (The 52 elements in *Decks* are interchangeable, which allows me to shuffle a deck.) The data structure that holds a collection of different type elements is a record:

```
type Cards is
  record
    SUIT : Suits;
    RANK : Ranks;
  end record;
```

This says that an object of type *Cards* consists of a pair of objects, one object is called *SUIT*, and the other is called *RANK*. The object *SUIT* is of type *Suits*, and the *RANK* object is a *Ranks* type object.

Now I have to define *Suits* and *Ranks*:

```
type Suits is (CLUBS, DIAMONDS,
                     HEARTS, SPADES);
type Ranks is (TWO, THREE, FOUR,
FIVE, SIX, SEVEN, EIGHT, NINE, TEN,
         JACK, QUEEN, KING, ACE);
```

Suits is called an enumeration type because it has a finite number of values that can be enumerated. The four possible values are *CLUBS*, *DIAMONDS*, *HEARTS*, and *SPADES*. I could have listed them in any order if I were only going to play poker with this deck of cards, but I might some day want to play bridge. In bridge, clubs are the lowest ranking suit and spades are the highest. By listing them in the order above, I have given them their conventional order and can use < and > operators to compare the importance of two objects of type *Suits*.

Similarly, if I had said *type Ranks is (ACE, TWO, . . .)*, then the *ACE* would have been the lowest ranking value. Defining a type by enumerating values not only defines what the permissible values are, but it also defines their order of relationship.

Finally, I define *Hands*.

```
type Hands is
  array(1 . . CARDS_IN_HAND)
  of Cards;
```

This definition looks a lot like the def-

inition of a deck of cards, except I have used a named number to express the number of cards in a hand. The definition of a named number is:

```
CARDS_IN_HAND : constant := 5;
```

Poker hands have five cards. If I were playing bridge, I would substitute the number *13* for *5* in the definition of *CARDS_IN_HAND*, and then everywhere in the program, the correct number of cards would be used.

Maranatha A differs from Ada in that only the first ten characters of a name are significant. I therefore had to use *CARDS_IN_HAND* and *CARDS_IN_DECK* instead of *CARDS_IN_A_HAND* and *CARDS_IN_A_DECK* because Maranatha A would interpret both the latter as *CARDS_IN_A*.

When I started writing the *Shuffle* and *Deal_A_Card* procedures, I quickly discovered a problem with the types *Decks* and *Hands*. When dealing from the deck, I needed to know how many cards were left in the deck. When dealing cards to a hand to replace discards, I needed to know which cards had been played (that is, discarded). I therefore had to redefine those data types. This did not, however, affect any of the rest of the program that I had already written. (If I had been writing this in assembly language and had reserved only 52 bytes for each deck of cards and 5 bytes for each hand of cards, I would have had to change storage size and indexing schemes if I had changed the structure of *Decks* and *Hands*.)

The complete definition of a deck of cards includes the number of cards left in the deck and an array of cards:

```
type Decks is
   record
      CARDS_LEFT : integer;
      FAN: Fans(1. .CARDS_IN_DECK);
end record;
```

I chose to call an array of cards a fan:

```
type Fans is
   array(integer range < >)
                              of Cards;
```

This is a slightly more general array definition than I have used before. The first array definition I used was *is array(1 . . 52)*, which meant that the array index was an integer in the range 1 to 52. It may surprise you that I have to specify the index as an integer. Other languages may take this for granted because the index can't be anything other than an integer. Ada allows you to use any discrete data type as an index, so it is possible to write an array definition such as *is array(CLUBS . . SPADES)*. (You can't use a continuous data type as an index because it doesn't make sense to look up the 3.14159th element of an array.)

The general form of the array definition uses the < > symbol, which is called a box in Ada. The general form allows you to define the array without forcing you to specify the size that it should be.

The complete definition of the hand of cards also has a fan of cards, but the fan in a poker hand has 5 elements instead of the 52 elements in a fan in a deck.

(Continued from page 47)

```
type Hands is
   record
      PLAYED :
Status(1. .CARDS_IN_HAND);
      FAN : Fans(1 . . CARDS_IN_HAND);
   end record;

type Status is
   array(integer range < >)
                    of boolean;
```

A hand of cards can be visualized as two five-element arrays. One array (the *FAN*) can be thought of as five slots that can each hold a single card. The second array (the *PLAYED* array) can be imagined as five signs placed in front of each card in the *FAN*. Each sign can have one of two messages written on it—it can say "This card has been played" or "This card has not been played."

Ada also has a predefined data type called Boolean, which can have one of two values—*TRUE* or *FALSE*. This allows us to write simple expressions such as *if PLAYED = TRUE* then. . . . Some languages use 0 and −1 to represent true and false, so the programmer has to remember that 0 means a card has been played.

Verb Definitions

Ada has two kinds of verbs—procedures and functions. So far, I have introduced three procedures (*Open_New*, *Shuffle*, and *Deal_A_Card*) and no functions. I'll talk about functions later.

All procedures have the same general form as that given in Listing Two, page 86. There are five keywords (*procedure*, *is*, *begin*, *exception*, and *end*), followed by information specific to the procedure. For convenience I've called the locations that contain specific procedure information *1 through *5. The keyword *exception* and information in locations *2, *4, and *5 are optional.

Open_New in Listing Three, page 86, is a good example procedure because it uses all five keywords and has information in all five locations. *Open_New* creates new decks of cards. The main program simply says *Open_New(RED_DECK)*;, and the procedure creates a new deck of cards called *RED_DECK*.

Notice that the statement ends with a semicolon. Some languages won't let a single program statement be more than one line long, but Ada ignores the carriage-return/line-feed sequence, so you can use them freely to make the program as readable as possible. It does mean, though, that you have to tell Ada where the statement ends by using a semicolon. (There is one exception—a carriage return marks the end of a comment.)

A procedure name, and possibly a formal parameter, go in the location marked *1. Here *formal* is used in the sense of showing the form rather than meaning prim and proper.

In *Open_New*, for example, *Open_New* is the name of the procedure, and the object *DECK* is a formal parameter that stands for any object of type *Decks*. The word *out* tells Ada that *DECK* is an output from the *Open_New* procedure and should not be erroneously used as an input. In other words, *Open_New* considers *DECK* to be a write-only variable.

(Continued from page 48)

Location *2 is used to create some temporary objects that will cease to exist when the procedure is finished. *Open_New* creates two such objects—the variable *i* is an integer used as an index, and *CARD* is a blank piece of cardboard on which *Open_New* prints a rank and a suit and then puts them in the *DECK*. You can give a variable an initial value when you create it. I gave *i* the initial value 0 but did not give *CARD* an initial value.

The work gets done in the area marked with the third star. You've probably seen FOR . . . NEXT loops before but not ones like those in *Open_New*. Usually FOR . . . NEXT loops are restricted to integers or, perhaps, real numbers. Ada can use any discrete variable as a loop index. The variable *S* is given the values *CLUBS*, then *DIAMONDS*, then *HEARTS*, and finally *SPADES*, as the outer loop is executed four times. Similarly, the variable *R* takes on the values *TWO* through *ACE*.

Remember that objects of type *Cards* have two components—a *SUIT* of type *Suits* and a *RANK* of type *Ranks*. The compound name *CARD.SUIT* is "selected component" notation that means the *SUIT* object (or component) in the *CARD* object.

Each of the four times the program works through the outer (*Suits*) loop, it works through the inner (*Ranks*) loop 13 times. The index counter should be 4×13 when all the looping is done, so the *CARDS_LEFT* component of *DECK* should receive the value 52.

The last statement in the *3 area is an error check. It is really a pair of statements as far as Ada is concerned. (Remember, a semicolon is an end-of-statement marker.) I like to put simple *if* statements, such as this one, all on one line because it is easier to read. Because Ada doesn't care about carriage returns, you can put multiple statements on one line if you wish.

The /= sign means not equal. Pascal programmers would probably prefer to use < > for that purpose, but the designers of Ada had already used that symbol for unconstrained arrays and wanted to have a separate symbol for inequality. It is an easy error for compilers to catch, so all the Ada compilers I have seen will tell you exactly what's wrong if you use < > by mistake.

The purpose of the *if* statement is to raise the exception *DECK_ERROR* if the final value of the index (that is, the number of cards created) does not equal *CARDS_IN_DECK*. An exception is simply an error flag. If an error is detected, the statements in area *4 are executed. Normally the exception handler is skipped, and program jumps down to the *end* statement. The *end* statement repeats the procedure name at *5 so Ada can check to see if you accidentally left out an *end if* or *end loop* statement somewhere. The name in area *5 must match the name in *1 exactly, except that uppercase and lowercase differences are ignored. (*OPen_New* matches *Open_new*, for example.)

Packaging General-Purpose Routines

Listing Four is an Ada construct called a package. A package is a collection of data types and objects (con-

(Continued from page 50)

stants and variables) that are specific instances of those data types and operations that manipulate those objects. The package has a name (*PLAYING_CARDS*) and can be used by other programs that ask for it by name. It is divided into two parts. The package specification (Listing Four A, page 86) explains what the objects and operations are but does not give all the intricate details about the objects nor explain how the operations work. The second part (Listing Four B, page 88) is the package body, and it contains all those details.

There are several reasons for breaking the package in two. Most of them are because Ada was designed for large programs that require more than three programmers. Two or three programmers can usually work together easily, but when a program turns into a committee project, it is harder for individual programmers to keep track of the whole program. Ada's package specification allows work to be partitioned and assigned logically. In this example, it tells one programmer that he must write a procedure called *Open_New*, which creates an object of the type *Decks*, and it tells the second programmer that he can assume the existence of a procedure called *Open_New* that will create decks of cards for him. The second programmer therefore does not need to wait for the first programmer to write *Open_New* before he can begin his part of the job.

Another advantage of Ada's package specification is that if, for example, I discover a better way to shuffle cards, I can change the implementation of *Shuffle* in the package body without affecting any other part of the program. I can also be sure that no other programmer has made use of some special quirk in my previous method because no one knew how I did it before.

From a software vendor's point of view, the advantage in separating the body from the specification is that the body can be supplied in object code. The purchaser of the package then does not know how the package works, so he can't copy the design. If he wants to modify it, he has to pay the vendor to change it.

Nested Packages

The first two statements in the package body of *PLAYING_CARDS* (file CARDB.ADA in Listing Two) are:

```
with CON_IO; use CON_IO;
```

CON_IO is a collection of console input and output routines. I could have used a common Ada package called *TEXT_IO*, but I chose not to. Maranatha A doesn't check to see which package routines are needed, so it loads all of the *TEXT_IO* package routines whether it needs them or not. I made a copy of *TEXT_IO*, deleted all the disk interface routines, and renamed it *CON_IO*, to reduce the size of the object code generated.

TEXT_IO is not the only I/O package allowed in Ada, it is just one that is guaranteed to make your programs portable. (*TEXT_IO* is the equivalent of CP/M BIOS—it provides a universal

(Continued from page 52)

I/O interface to a specific hardware configuration.) I was not worried about portability because the final product will need special I/O routines that input and output silver dollars, which can't possibly be portable because of hardware limitations. *CON_IO* is just a temporary I/O package that lets me substitute a CRT for a coin detector and a dollar dispenser.

Maranatha A does not support generic routines, so *CON_IO* includes an instantiated *INTEGER_IO* package (rather than the generic package Ada would use).

The *with* clause tells Ada that a package named *CON_IO* is stored in a file on the system disk. Ada should read this file to find out what data types, procedures, and functions have been defined by that package. The *use* clause tells Ada that she can use these items as necessary to satisfy the program requirements.

CON_IO contains a procedure to output a character string. The form of the procedure is:

```
put("A text string.");
```

Because Ada has been told to compile the Draw Poker program in the context of the *CON_IO* package, she knows the definition of *put* so I do not need to define it.

Mimicking Other Languages

You may have noticed that the package body of the *PLAYING_CARDS* package includes the phrase *with APL; use APL;*. The computer language APL is different from most other languages because it has a function called *Deal* that is useful in programs that play cards. The *Deal* function returns a random sequence of numbers without repeating any number, which makes shuffling cards easy. Because I have already written a package to simulate some APL functions (the pertinent part is given in Listing Five, page 90), all I have to do is tell Ada that the *PLAYING_CARDS* package needs to be compiled with APL, so all *APL* data types, procedures, and functions are available.

Unlike Maranatha A, true Ada would allow me to omit the phrase *use APL;*. Instead, I could use dot notation to tell it which package to use—that is, I could write a statement such as

```
SEQUENCE :=
    APL.Deal(CARDS_IN_DECK,
    CARDS_IN_DECK);
```

This means that the variable *SEQUENCE* gets a value computed by a function in the *APL* package called *Deal*. The sequence (the first *CARDS_IN_DECK* in the argument list) contains 52 numbers in the range 1 to 52 (the second *CARDS_IN_DECK* in the argument list).

Ada knows where to find the *Deal* function, but a human reading the program might not. I wanted to use the dot notation to help remind me that *Deal* is an *APL* function. Maranatha A does not allow the dot notation, so I had to use a *use* clause instead.

Nested Functions

In the Draw Poker program, I need to know if two (or more) cards have the same rank to see if I have two-, three-, or four-of-a-kind. If I couldn't nest functions (that is, if I could do only one function at a time), I would have to use several statements to find out if two cards have the same rank. For example, if I wanted to find out if cards 3 and 4 in *MY_HAND* have the same rank, I would have to do something like

```
FIRST_CARD :=
Card_Number(3, MY_HAND);
FIRST_RANK :=
Rank_of(FIRST_CARD);
SECOND_CARD :=
Card_Number(4, MY_HAND);
SECOND_RANK :=
Rank_of(SECOND_CARD);
if FIRST_RANK =
SECOND_RANK then . . .
```

It is clearer to put it all in one statement, though:

```
if Rank_of(Card_Number(3,
MY_HAND) = Rank_of
(Card_Number(4, MY_HAND)
then . . .
```

The function *Card_Number* pulls card 3 (or 4) out of *MY_HAND*, and then the *Rank_of* function reads the rank of that card.

The Whole Program

The whole program is given in Listing Six, page 91. It begins with three comment lines that give the file name of the program, the date when it was written (or revised), and the author's name. The context clauses tell Ada that the *Draw_Poker* procedure should be compiled in the context of the *CON_IO* and *PLAYING_CARDS* packages, so all the procedures, functions, and data types in those packages are defined and usable.

Draw_Poker requires a special data type, called *Values*. The value of a poker hand can be *NOTHING* up to *ROYAL_FLUSH*, so this type definition enumerates all the possible values in ascending order of importance.

Draw_Poker also requires five variables (objects)—a *STOCK*; one *PLAYERS_HAND*; a *WAGER* and a *PAYOFF*, which are both integers; and a *VALUE*, which can have any of the values *NOTHING* through *ROYAL_FLUSH*.

Next, the procedure *put* is defined for what seems to be the millionth time. Procedures that have more than one meaning are called overloaded procedures. *CON_IO* has a *put* for individual characters, a *put* for character strings, a *put* for integers, a *put* for floating-point numbers, and a *put* for Boolean values. Listing Four contains a *put* for suits, a *put* for ranks, a *put* for cards, and a *put* for hands. Finally, I now have a *put* for values of poker hands.

If Ada wasn't smart enough to figure out which *put* to use, I would have to make up separate names to output integers, floating-point numbers, characters, strings, Booleans, suits, ranks, cards, hands, and values. Then I would have to remember which name I used for each data type. Because Ada allows me to reuse names, though, all I have to remember is that *put* outputs anything, and Ada has to remember how to output each object.

If an external package name is given (for example, *APL.Deal*), Ada will look only in that package for the procedure. If no external package name is given, she will look for a definition of the procedure in the declarative region (the area marked *2 in Listing Two).

If Ada can't find the procedure in its list of procedures currently defined by the program, and there is a *use* clause, she will look for the procedure in the "*used* package." If there are two *used* packages and both have a procedure with the correct name and formal parameters, then Ada won't know which one to use. She will explain her dilemma during the compilation of the program (rather than just picking one at random), and you will have to provide an external package name to let her know which procedure to use.

(Continued from page 55)

Separate Compilation

The *Draw_Poker* procedure needs to compute the value of a hand. I chose to compile this separately, so I wrote a "body stub" where the function would normally go. The body stub is:

```
function Value_of(HAND : Hands)
   return Values is separate;
```

This tells Ada that a function called *Value_of* operates on a *HAND* and returns an object of type *Values* (that is, *NOTHING* through *ROYAL_FLUSH*) and that this function will be compiled separately. (See Listing Seven, page 91.)

Compiling *Value_of* separately has three advantages. First, it divides the labor effectively. Sometimes adding more programmers to a project slows progress because each programmer has to know how another programmer has written part of the program before starting his own part. Separate compilation defines the interfaces between program modules clearly and allows all the programmers to work in parallel, thus shortening development time.

Second, separate compilation makes it easier to test procedures and functions. If the *Value_of* function were an inseparable part of the *Draw_Poker* procedure, think how long it would take you to find out if *Value_of* recognizes when a hand contains a *ROYAL_FLUSH*. Because *Value_of* is compiled separately, though, you can write a program that tests *Value_of* by asking what five cards are in the hand and then calling *Value_of* to see if it figures out the value of the hand correctly.

Third, separate compilation makes it easy to fix mistakes. As a matter of fact, *Value_of* does have a mistake. I don't play poker, so it wasn't until I showed the program in class that I found out aces can be high or low. *Value_of* doesn't realize that *TWO, THREE, FOUR, FIVE, ACE* is really the same as *ONE, TWO, THREE, FOUR, FIVE* and should be considered to be a *STRAIGHT*. Because *Value_of* is separate from *Draw_Poker*, it was easily fixed, recompiled, and relinked to the other modules. (See Listing Eight, page 92, for corrections.)

Separate compilation and inclusion of packages makes it difficult to compare Ada compiler speeds with other language compilers. It's fair to compare one Ada compiler to another on the basis of number of lines compiled per minute, but it isn't fair to compare Ada lines per minute to Pascal lines per minute (for example) because a Pascal compiler has to compile the whole program every time a change is made, while Ada just has to compile the part that has been changed. For a very long Ada program that has been properly divided into many modules, it might make more sense to measure the linker speed than the compiler speed.

The Final Product

Remember that this case study involved making a video Draw Poker game that would be sold for profit. The program described here has no graphics, doesn't accept coins, and the user interface is through a terminal. The product, as it now stands, isn't commercially viable.

If I were going to market the product, I would get a mechanical engineer to design a coin detector that could reject slugs and count the number of genuine silver dollars entered. Meanwhile, I would write another procedure *get* so that *get(WAGER);* would accept input from the coin detector. I would put this procedure in a package called *HARDWARE_IO*. I would then write a simple program based on this sequence of statements:

```
loop
   HARDWARE_IO.get(WAGER
   CON_IO.put(WAGER);
end loop;
```

I could then drop coins in the slot and see if the CRT screen displayed the correct number of dollars.

The mechanical engineer would also design a dollar dispenser, which would require a *HARDWARE_IO.put* routine. When the dollar dispenser and *put* procedure were finished, I could test them using a program containing these statements:

```
loop
   CON_IO.put("How much should I
                              pay?");
   CON_IO.get(WINNINGS);
   HARDWARE_IO.put(WINNINGS);
end loop;
```

Simultaneously, an electrical engineer would work on a graphics interface that could display playing cards. It would need a *HARDWARE_IO.put* procedure for *Cards*, which would replace the *PLAYING_CARD.put* procedure.

From Host to Target

I think you can see how Ada's modular nature makes it easy to put a system together. After you have tested each interface, you can integrate it into the Draw Poker program simply by replacing the *CON_IO* procedure with the corresponding *HARDWARE_IO* procedure.

Imagine how difficult it would be to get a working system if the Draw Poker program (including *HARDWARE_IO, PLAYING_CARDS, APL*, and *Value_of*) were one long spaghetti-code program written by a team of programmers. Someone would always be waiting for someone else to finish something, and the program couldn't be tested until all the hardware was finished.

Ada's modular form lets you develop embedded system software on a host computer (even a micro) using simulated I/O drivers. You can develop test procedures using these simulated drivers, which you can then replace by real drivers in any order. You can test the real drivers quickly using the methods you used to test the simulated drivers. Integration should be a trivial task.

In the ideal case (that is, with unlimited manpower and resources), the time taken to complete the project is not much longer than the time taken to complete the longest task. The concept of a critical path (where one task cannot begin until another is finished) disappears.

Micro Limitations

Maranatha A is not a true Ada compiler. It lacks overloaded operators, generics, and tasking, so you can't use it to develop programs that need these features. CP/M-80 systems typically have about 48K to 57K of usable program memory, so that limits the size of the program you can actually run on the micro host. Remember that Ada's modular form lets you compile and test modules separately, so you could test all the pieces of a huge program even if you couldn't

(Continued from page 56)

run the whole program on the host.

I didn't feel hampered by Maranatha A. When I was beta-testing it, I didn't bother to read the whole *Maranatha A Language Reference Manual* (*LRM*). I read just the Ada *LRM* and assumed Maranatha A would do what Ada does. I referred to the Maranatha manual only when Maranatha A wouldn't do something that Ada should do.

Maranatha A did not then have overloaded operators (it may have them by the time you read this), so I couldn't use the plus sign to add cards to a hand. I would have liked to have been able to write

```
PLAYERS_HAND :=
PLAYERS_HAND
+ Top_of(STOCK);
```

but as I couldn't, I used

```
Deal_A_Card(PLAYERS_HAND,
  STOCK);
```

instead.

I wanted to use dot notation to emphasize that the *Deal* function is in the *APL* package, but I suppose that I could have just as easily used a comment to do that.

Maranatha A doesn't have an IMAGE attribute, which made the *put* procedures for *Suits* and *Ranks* more complicated than they need be. For enumeration types with 4 to 13 values, it isn't too bad to have to use a *case* statement as I did, but if the enumeration type had 50 or 100 values, it could be annoying to have to output values in that way.

The extraneous semicolon in *separate (Draw_Poker);* confused me for a while, but I think that error has been removed from the version that Supersoft is now selling. The exception handler also contained a bug, which forced me to include the guard in the expression:

```
when DECK_ERROR |
          CONSTRAINT_ERROR =>
  raise DECK_ERROR;
```

If not for the bug I could simply have written *raise DECK_ERROR;*. I think that bug has also been fixed in Supersoft's version.

It is a minor inconvenience that only the first ten characters of a name are significant. I lived for years with a FORTRAN language that permitted only six-character names, and it was picky about what the first letter was.

Now that I have a real Ada compiler with generics and tasking, I realize how valuable they are, but when I wrote the Draw Poker program I didn't know what I was missing, so it didn't bother me much. The Draw Poker program didn't need them, anyway.

The worst problem with my betatest version is that a missing semicolon causes the compiler to crash. This was a real nuisance at first because I did not know any Pascal before I learned Ada, so I wasn't in the habit of ending statements with semicolons, and it crashed often.

The built-in random-number generator is not standard with Ada, and it was a handy function to have for Draw Poker. If I ever want to run this program on a validated Ada compiler, I will have to write a random-number generator to replace *RND* in the *APL* package.

Using a micro to develop Ada programs isn't ideal. It would be better to use a validated Ada compiler on a mainframe computer, but if you don't have $30,000 to spend on a compiler (and a VAX-780 to run it on), then Maranatha A is a good alternative.

DDJ

(Listings begin on page 76)

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Equivalent Program Segments

```
;-------PROMAL--------
REPEAT
   PROMPT_AT 5,24, "Add/Chg/Quit?"
   IF Reply = 'A'
      ADD Item
      New_Items = New_Items + 1
   ELSE IF Reply = 'C'
      CHANGE Item
UNTIL Reply = 'Q'
```

```
11910 REM-----BASIC---------
11920 CL=5:LN=24:PR$="Add/Chg/Quit?"
11925 GOSUB 9490:REM GET REPLY
11930 IF RP$<>"A" THEN 11950
11940 I9=IT:GOSUB 10100:REM ADD
11945 NI=NI+1:GOTO 11920
11950 IF RP$<>"C" THEN 11970
11960 I9=IT:GOSUB 6050:REM CHG
11970 IF RP$<>"Q" THEN 11920
```

PROMAL is readable and understandable. You see the logic from the structure. And PROMAL lets you call procedures by name – so no more GOSUBs. But there's more.

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- Predefined DATA of any type
- Multi-Dimensional Arrays (any type)
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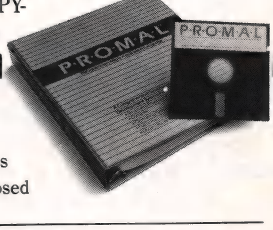

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Overview of the DOD Ada Software Repository

by Richard Conn

With Ada becoming available for micros, this base of public-domain software is a good way to learn. The Ada Software Repository is over 20 megabytes in size.

A repository of Ada programs, Ada software components, educational material, and Ada-oriented information has been established on the SIMTEL20 host computer on the Defense Data Network (DDN). This repository, established on November 26, 1984, is accessible to thousands of host computers on the more than 80 subnetworks that comprise the DDN. Access to this repository will be provided to the Ada community at large in the near future; with validated Ada compilers becoming available for popular microcomputers, this large base of public-domain Ada software and information will be a good way to introduce yourself to Ada and learn more about it.

The repository on SIMTEL20 serves two purposes: to promote the exchange and use of Ada programs and tools (including reusable Ada software components) and to promote Ada education by providing several working examples of programs in source form for people to study and modify. It also contains other useful information.

The repository is divided into several subdirectories by topic. Table 1, page 61, shows the general topic areas, the subdirectory names, and the sizes of the documentation and source-code files in each subdirectory. Today the DOD Ada Software Repository contains more 300 files, totaling more than 20 megabytes in size.

Richard Conn, 6300 Roundrock, Apt. 3008, Plano, TX 75023

Tour of the Ada Repository

In the following paragraphs, I will take you on a brief tour of the Ada Software Repository. I will cover only selected points of interest and follow Table 1.

The first topic is "General Information," under which is the Education subdirectory. A glossary of Ada terms, a listing of Ada and Ada-related textbooks, a bibliography of Ada textbooks (which includes comments on the books and their audiences), an example of object-oriented design, productivity data (which presents data from live projects coded in Ada), and an example of how Ada can interface with other languages are some of the items of information available here.

The General subdirectory contains many tidbits of information, ranging from databases on the repository to tutorials on how to transfer files on the DDN.

The Pointers subdirectory contains information on where to look for sources of information and Ada software outside the repository. The large collection of Ada compiler benchmarks on USC's ECLB host computer, the address of the DOD Software Engineering Institute, the INFO-ADA database on ECLB (which provides listings of conferences and current events), and a list of all validated Ada compilers are some of the items contained or referenced in this subdirectory.

The second topic is "Reusable Components." Reusability of software without the need for a complete redesign is supported by Ada, and subdirectories such as Components, Math, and Virterm were established to contain software components that may be reused time and again in various applications.

Three dynamic string packages, a generic quick-sort, two linked-list packages, a Unix-style ARGC/ARGV parser, and a command-line interpreter are some of the items found in Components. Math includes a math library of log, trig, exponential, and other functions and libraries of matrix-, bit-, and set-manipulation routines. Virterm contains virtual terminal packages, including a Curses package modeled after the Curses of Berkeley Unix.

The third topic, "Software Development Aids," includes toolsets for compilation order, Ada style, and metrics analysis of Ada programs; software project-management tools; Ada cross-reference programs; three Ada pretty printers; and a library file manipulation tool (Pager, which groups smaller files into larger library files).

The communications software includes an implementation of the TCP/IP communications protocol (the DOD standard) and file transfer (FTP), mail handling (SMTP), and host-to-host (TELNET) communications programs.

For graphics fans, the Graphical Kernel System (GKS) has been implemented in almost 2 megabytes of Ada code.

Finally, a library of Ada compiler benchmarks (different from the one on ECLB), two text-file editors, a spelling checker/corrector, an LALR(1) grammar for Ada that may be processed under the LEX/YACC tools of Unix, an EMACS front-end for the development of Ada software, and a program that can configure a TVI970 terminal are some of the items found under the "Other Topics" category.

How to Get Software

If you access a computer on the DDN (on the ARPANET, MILNET, or any other DDN subnet), you may subscribe to the Ada Software Repository mailing list by sending an electronic mail message to ADA-SW-REQUEST@SIMTEL20. In response to your message, you will be placed on the ADA-SW mailing list, over which notices of changes, updates, bugs, and other repository-oriented information are distributed. You will also receive a welcome message that details how to access the repository from a DDN host computer.

If you do not have access to a DDN host computer, a nine-track magtape distribution facility is being established from which any member of the Ada community will be able to acquire a tape of the entire Ada Software Repository. Also, submission of some or all of the software and documentation in the repository to the public-domain PC-BLUE library is being considered. [DDJ *will announce these public-access opportunies when they become official.—ed*]

Limited DDN access is available to members of the Ada community with approval of the Ada Information Clearinghouse. A public account sponsored by the AdaIC on a DDN host computer at the University of Southern California (USC-ECLB) host computer provides access to current information on the Ada initiative and the ability to link with the SIMTEL20 host computer, scan the subdirectories of the DOD Ada Software Repository, and transfer files from the repository. These files can then be viewed on the ECLB computer or transferred to a PC. To obtain the telephone number and access codes required to access the ECLB ADA-INFORMATION account maintained by the AdaIC, send conventional mail or telephone:

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The DOD Ada Software Repository is supported by the U.S. Department of Defense, U.S. Army, White Sands Missile Range.

DDJ

(Listings begin on page 86)

Topic	Directory	Documentation (Bytes)	Source Code (Bytes)
General Information	EDUCATION	195,010	0
	GENERAL	515,205	0
	NOSC-TOOLS	121,531	0
	POINTERS	133,680	0
		965,426	0
Reusable Components	COMPONENTS	96,831	859,493
	MATH	12,367	138,761
	VIRTERM	913,414	597,130
		1,022,612	1,595,384
Software Development Aids	COMPILATION-ORDER	87,124	359,990
	CROSS-REFERENCE	4,457	23,786
	MANAGEMENT-TOOLS	323,686	513,434
	METRICS	304,729	1,390,255
	PAGER	25,442	95,528
	PRETTY-PRINTERS	94,014	659,742
	STUBBER	12	81,309
	SYTLE	227,791	1,595,247
		1,078,855	4,719,291
Communications Software	DDN	30,822	1,959,099
	MESSAGE-HANDLING	242,840	977,501
		273,662	2,936,600
Graphics and Display Tools	FORMGEN	305,823	632,772
	GKS	322,595	1,991,575
	MENU	367,593	450,093
		996,011	3,074,440
Other Topics	BENCHMARKS	73,733	302,163
	EDITORS	113,372	144,099
	EXTERNAL-TOOLS	25,043	80,520
	SPELLER	387,012	1,777,350
	STARTER-KIT	18,409	83,903
	TOOLS	59,876	323,340
		677,445	2,711,375
TOTAL		5,014,011	15,037,090

Table 1

Data Abstraction with Modula-2

by Bill Walker and Stephen Alexander

The ability to separate the definition of a data structure from the details of implementation is important.

Introduction

This short article is intended to illustrate the concept of data abstraction via the use of the programming language Modula-2. We accomplish this by presenting a sample program that may prove useful in its own right.

We must understand the notion of data abstraction before we can appreciate the utility of the methods presented here. Let us define a priority queue as a collection of data, along with two operations, *add* and *fetch*, which maintain that data on a smallest-item-first (or largest-item-first) basis.

Suppose we have a magic jar that we are free to add or remove data items to or from any time we please. The data we add to the jar is randomly ordered. When we reach into the jar and grab a data item, we are guaranteed that the item will be the smallest data item in the jar. It may not be the smallest that we have seen because we have no idea what data has already been removed from or added to the jar. Our magic jar is acting as a priority queue.

Of major importance is the fact that we have no knowledge of the mechanism of the jar. Internally, we do not know if the jar operates by maintaining a computer sorting procedure that is in constant operation or by keeping an especially industrious collection of elves. Nor do we care.

We are interested only in the action of the jar itself, not in its internal mechanism. We may regard the jar as an abstraction of a priority queue.

We should be aware that the jar has many uses. We can use it as a sorter, for example, by dumping a whole collection of numbers into it and then fetching them one at a time.

Languages to Support Data Abstraction

Almost any computer language in use today will allow us to write a computer program that will implement a priority queue either by using a static array or by creating a dynamically allocated linked list. The problem with most of these languages is that the method of handling the priority queue is intimately wedded to the abstraction of the queue. There is no convenient method of making a priority queue available to a user without also making the unnecessary details of the implementation available. A few languages, or more commonly language implementations, represent exceptions.

The ability to separate the definition of a data structure from the details of implementation is an important one. This ability is present in several modern languages and in particular is present in the language Modula-2, which has recently received considerable attention.

An Example

Modular design charts as presented in *Software Engineering with Modula-2 and Ada* by Sincovec and Wiener[1] represent a natural expression of abstract solutions to software problems. It follows that modular design charts are particularly well suited for use in projects employing programming languages that allow high levels of abstraction. Figure 1, page 63, illustrates a modular design chart of a small software system.

The system represented will be used to generate random numbers and sort them using a priority queue. By examining the chart, we see that the system will consist of a module to generate the pseudorandom numbers; a module to provide the means for handling our abstract priority queue; and a program, Sorter, to tie together the functions supplied by our small "library."

Note that the software bus details the pathways of communication required by the separate modules of our system. The software bus is analogous to a hardware communications bus found on modern computers.

In the design of our chart, we have been careful to minimize the communication required between the modules. By minimizing communication, we have contributed greatly to the dependability and maintainability of our system.

We present a Modula-2 program that follows the scheme of our modular design chart. Our program will generate 100 pseudorandom num-

Bill Walker and Stephen Alexander, Dept. of Computer Science, East Central University, Ada, OK 74820

bers and place them each into a priority queue. After the queue is built, we will remove the numbers from the structure and print them one at a time. The definition of a priority queue assures us that the numbers will be in ascending (or perhaps descending) order. The step from the modular design chart to actual Modula-2 code is often a surprisingly small one.

In this example program, we have "imported" the functions that are designed to deal with the priority queue. We consider that this program is a client of MODULE Queues, which supplies required queue-handling functions. When we write the program, we are entirely ignorant of the method used to implement the priority queue. We can make the same comments about the random number generator *randu( )* and its parent module RandomNumbers. We have no idea at all how it works, just that it does. Notice that the program is a direct reflection of the abstract design.

The two modules RandomNumbers and PriorityQueue provide procedures that support the MODULE Sorter (Listing One, page 94). The following section provides a rather complete description of the information a programmer needs to make use of these two modules.

The Definition Modules

Let us first turn our attention to DEFINITION MODULE RandomNumbers (Listing Two, page 94). In this module, we find that a function procedure named *randu* is exported (made visible) so that other modules can use it. We see that the function procedure *randu* does not require any parameters and that the result type is INTEGER. We have been able to glean all this information by examining the definition module alone. It was not necessary to have any knowledge at all of how the random number generator does its job. The module RandomNumbers is able to provide services to its clients while masking (protecting!) its own internal functions from those clients.

In a like manner, DEFINITION MODULE Queues provides us with all the tools we need to utilize priority queues without providing any access to the internal workings of those queues. This module exports the type PriorityQueue so that user programs may declare compatible objects of this type. It also provides a means of initializing such queues (PROCEDURE InitPriorityQueue) and for adding items to a queue or fetching an item from a queue. There is also a function procedure that can determine if a given queue is empty. (In a production environment, MODULE Queues would probably contain additional queue-handling procedures. For purposes of illustration, this subset should be sufficient.)

These procedures provide us with a system for manipulating priority queues. MODULE Sorter is an example of how we can use the objects from RandomNumbers and Queues to make a useful program.

Please note that in most recent versions of Modula-2, the EXPORT lists are not required. In these newer versions, the declarations themselves serve as the EXPORT list for the definition modules[2]. In MacModula-2 (from Modula Corporation), the EXPORT lists are required.

Compiling the Programs

Modula-2 allows for the compilation of both the definition modules and the client program Sorter without concern for the details of implementation. This is important because it allows us to detect any errors in the design of the interface of our system. For instance, if Sorter incorrectly provides us with the wrong number of parameters to one of the imported procedures, the compiler will supply us with ample warning. This feature is in contrast to such languages as C, which would not flag such an error.

The compiler is sufficiently sophisticated to allow explicit type checking across the boundaries of separately compiled files. It is commonplace to compile each of the definition modules individually and to provide them as libraries for the use of the main program.

At this point, we compiled each of the above-listed programs under MacModula-2 on a 512K Macintosh. It is necessary that both definition modules be compiled before MODULE Sorter because Sorter is a client of these modules. The order of compilation of the definition modules is arbitrary because neither is dependent upon the other.

Implementation Issues

In this section we provide implementation modules for each of the above-defined modules RandomNumbers and Queues.

A library module consists of an interface (definition module) and an implementation (implementation

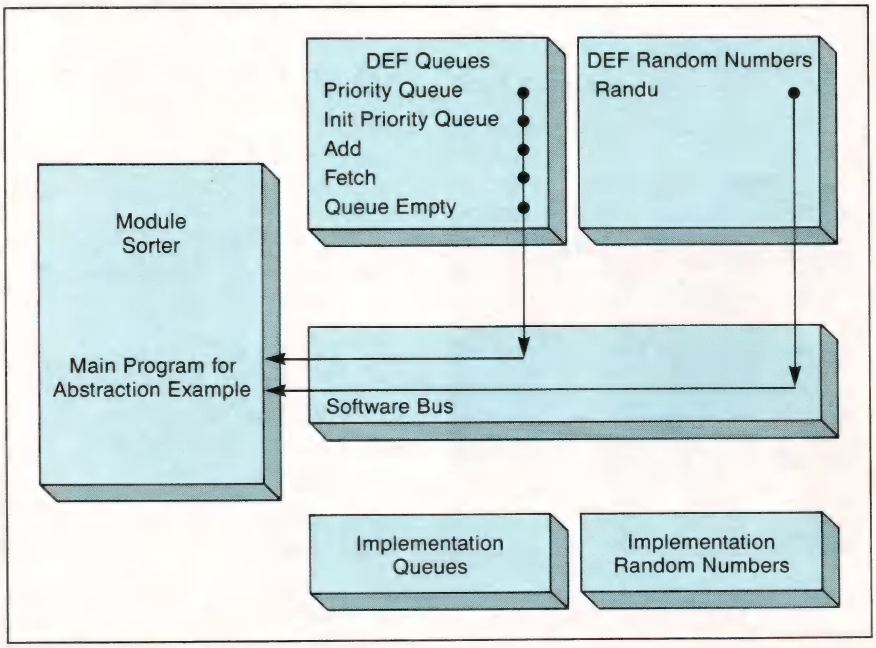

Figure 1

(Continued from page 63)

module). After compiling the implementation modules, we have complete library modules that are available to any client. In production environments it is important that system maintenance be convenient. Modula-2's library concept allows for this needed convenience.

Now we will discuss the implementation components of our small library and illustrate the exceptional ease of maintenance afforded by Modula-2.

Note that the procedures and modules listed in Listings Three and Four (page 95) that are not discussed are part of a standard library of interfaces provided with the MacModula-2 system. It is necessary to import the utilities Allocate and Deallocate from storage in order to use the standard procedures New and Dispose. A discussion of these standard utilities may be found in Niklaus Wirth's *Programming in Modula-2*[2]. We feel that the mnemonic value of these declarations is great enough that further discussion of them is not required.

We have chosen to implement Queues via the mechanism of a dynamically allocated linked-list structure. Upon examining the implementations, we see first that the code is easily read and much akin to Pascal. Upon closer examination we discern that the Add procedure is a well-known recursively defined algorithm. At this point we recognize that we might later wish to change this procedure to a nonrecursive algorithm. If we do so, it will not be necessary to recompile either the of the definition modules or the MODULE Sorter. The only recompilation necessary will be that of IMPLEMENTATION MODULE Queues.

The random number generator in IMPLEMENTATION MODULE RandomNumbers is an example of the classic linear congruential multiplicative pseudorandom number generator of the type discussed in Knuth's text[3], among others. However, we have chosen the coefficients for the recurrence relation poorly. If we recognize this, say after using MODULE Sorter for six months or so in a production environment, we can simply replace the coefficients with more appropriate ones and recompile the IMPLEMENTATION MODULE RandomNumbers. Because it is not necessary to recompile Sorter, a user of the system might be totally unaware that we have made any changes.

If we find that the uses of our system are not well suited to recursion, we may change PROCEDURE Add of IMPLEMENTATION MODULE Queues to a nonrecursive routine. Once again, it will be necessary to recompile only IMPLEMENTATION MODULE Queues to effect the change.

Before the changes were made, our system was capable of sorting fewer than 1,000 pseudorandom numbers; however, after we installed the nonrecursive version of Add, we used the system to sort more than 4,000 random numbers. (This feat was accomplished overnight. Insertion sorting is as slow sorting method!) In addition, the range of the pseudorandom numbers generated by *randu* was increased from 0 . . 6 to 0 . . 4095.

Conclusion

In addition to the features of the language shown here, Modula-2 also offers procedure types, generics, open array parameters, low-level facilities, concurrent processes, and many other resources too numerous to mention in this article. Those readers interested in further study of Modula-2 are invited to examine the following list of sources.

Notes

1. Sincovec, R., and Wiener, R. *Software Engineering with Modula-2 and Ada.* New York: John Wiley and Sons, 1985.
2. Wirth, N. *Programming in Modula-2, Third Edition.* New York: Springer-Verlag, 1985.
3. Knuth, D. E. *The Art of Computer Programming,* vol. 2, *Seminumerical Algorithms.* Reading, Mass.: Addison-Wesley, 1981.

(Listings begin on page 94)

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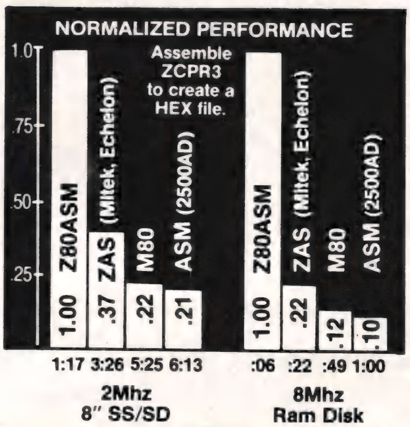

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Language Features

- Data Types: char, short, int, unsigned, long, float, double
- Data Classes: auto, extern, static, register
- Typedef, Struct, Union, Bit Fields, Enumerations
- Structure Assignment, Passing/Returning Structures

Functions

abs	conbuf	feof	getcseg	isascii	movmem	replace	strcat
asm	conc	ferror	getdseg	iscntrl	open	repmem	strcmp
asmx	cos	fflush	getd	isdigit	outp	rewind	strcpy
atan	cpystr	fgets	putd	islower	peek	right$	strlen
atof	creat	fileno	getdate	isprint	perror	rindex	strncat
atoi	cursblk	filetrap	gettime	ispunct	poke	rmdir	strncmp
atol	curslin	find	geti	isspace	poscurs	scanf	strncpy
bdos	curscol	floor	puti	isupper	pow	setbuf	strsave
bdosx	cursrow	fopen	getkey	itoa	printf	setbufsiz	system
bios	cursoff	fprintf	getmode	keypress	putc	setcolor	tolower
biosx	curson	fputs	setmode	left$	putchar	setdate	toupper
calloc	delete	fread	gets	len	puts	settime	ungetc
ceil	drand	free	getw	log	putw	setjmp	ungetch
cfree	exec	freopen	heapsiz	log10	rand	setmem	unlink
chain	execl	fscanf	heaptrap	longjmp	read	sin	write
character	execv	fseek	hypot	lseek	readattr	sound	writechs
chdir	exit	ftell	index	malloc	reach	sprintf	xmembeg
chmod	exitmsg	fwrite	inp	alloc	writech	sqrt	xmemend
clearerr	exp	getc	insert	mathtrap	readdot	srand	xmemget
close	fabs	getch	iofilter	mid$	writedot	sscanf	xmemput
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cmpstr	fdopen	getchar	isalpha	modf	rename	str$	_exit

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C CHEST

LISTING TWO (Text begins on page 16)

```
-----------------------------------------------------------------------
#include <stdio.h>
#include <ctype.h>

/*      HIST.C  Support for Unix-like history. In addition, if ! is
 *              replaced with a ^ you'll be in edit mode before
 *              re-executing the command. Legal syntaxes are:
 *
 *        Copyright (C) 1985 Allen I. Holub. All rights reserved.
 *
 *
 *      non-edit          edit        function
 *        mode:           mode:       performed:
 *
 *         !!             ^^          repeat previous command
 *         !<num>         ^<num>      repeat cmd with hist number <num>
 *         !<pat>         ^<pat>      repeat cmd that matches pat.
 *         !> file                    Save history list to file
 *         !< file                    Restore history list from file
 *
 *      Externally accessable routines are:
 *
 *      void    print_hist(fp)    Print the history list along with
 *      FILE    *fp;              associated nums (for the !<num> command).
 *
 *      int     get_hnum()        Returns the history number that will be
 *                                associated with the next call to history.
 *
 *      void    history( buf, maxbuf)
 *      char *buf;                Add the contents of buf to the history
 *                                list. If buf contains a history request
 *                                (!! etc.) expand it too. In this case,
 *                                overwrite buf with the entry from the
 *                                history list. No more than maxbuf
 *                                characters will be copied.
 */

/*----------------------------------------------------------------------*/

extern  char    *strsave  ( char*                 );
extern  int     strmatch  ( char*, char*          );
extern  char    *efgets   ( char*, int,    FILE*  );

/*----------------------------------------------------------------------*/

#define MAXHIST    32             /*  Size of history list  */
#define START      Hist_list
#define END        &Hist_list[MAXHIST-1]
#define HIST_CH    '!'
#define EDIT_CH    '^'
#define READ_CH    '<'
#define WRITE_CH   '>'

#define DEF_HNAME "/histlist"    /* Default place to save history list with
                                  * !> or !< commands. (ie. no file given).
                                  */
/*----------------------------------------------------------------------*/
/* History list, maintained as a ring buffer:                           */

static char     *Hist_list[MAXHIST] =
{
            NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
            NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
            NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
            NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL
};

static char     **Hist_ptr = START;     /* Pointer into history list    */
static int      Hist_num   = 1;         /* Current history number       */

/*----------------------------------------------------------------------*/

static void     add_hist( cmd )
char            *cmd;
{
        /*      If cmd is non-null, add it to the history list.
         *      Commands are copied into a malloced buffer.
         */

        if( *cmd )
        {
                if( *Hist_ptr )
                        free( *Hist_ptr );

                if( ! (*Hist_ptr = strsave(cmd)) )
                        printf("Out of memory !!\n");
                else
                {
                        Hist_num++ ;
                        if( ++Hist_ptr > END )
                                Hist_ptr = START ;
                }
        }
}

/*----------------------------------------------------------------------*/

static   int    get_hist(buf, maxbuf, desired)
register int    desired;
char            *buf;
{
        /*      Copy the string associated with the indicated history
         *      number into buf if possible. Return 1 on success & 0 if
         *      the number isn't in the list (is too old). Negative
         *      numbers are treated as an offset from the current
         *      history number. If "desired" is 0 then we are
         *      searching for a pattern rather than getting a particular
         *      number. In this case the patern starts at buf[1];
```

```
         */

        register char   **p;

        if( !desired )
        {
                /*      A pattern was requested. Return 0 if you can't
                 *      find it. Otherwise, when the loop is done *p will
                 *      point at the correct string. Search the list
                 *      backwards starting at the most recently entered
                 *      number.
                 */

                for( p = Hist_ptr, ++buf ; 1 ; )
                {
                        p =  (p == START) ? END : p - 1 ;

                        if( !strmatch(buf, *p) )
                                break;

                        if( p == Hist_ptr || !*p )
                                return 0;
                }

                --buf;
        }
        else
        {
                /*      An actual history number has been requested:
                 *
                 *      1)      Convert a negative offset into an actual
                 *              history number if necessary.
                 *      2)      Then convert the history number into an
                 *              offset into the history list. Note that
                 *              this will be a negative offset even though
                 *              the result of this operation is positive.
                 *      3)      If the offset is out of range, return a 0
                 *      4)      Else convert the offset into a pointer into
                 *              the history list. If the pointer is off the
                 *              list wrap around to the other end.
                 */

                if( desired < 0 )                               /* 1 */
                        desired += Hist_num;

                desired = Hist_num - desired;                   /* 2 */

                if( desired < 1  ||  desired > MAXHIST )        /* 3 */
                        return 0;

                if( (p = Hist_ptr - desired) < START )          /* 4 */
                        p += MAXHIST;
        }

        strncpy( buf, *p, maxbuf );

        return 1;
}

/*----------------------------------------------------------------------*/

static  int     eget_hist( buf, maxbuf, desired )
char    *buf;
{
        /*      Works just like get_hist except lets you edit the
         *      command. Note that the string returned by this routine
         *      will be overwritten by the next call. Copy it somewhere
         *      if you need to save it.
         */

        register int    rval;

        if( rval = get_hist(buf, maxbuf, desired) )
                rval = (int) efgets(buf, maxbuf, stdin) ;

        return rval ;
}

/*----------------------------------------------------------------------*/

int     get_hnum()
{
        return Hist_num ;
}

/*----------------------------------------------------------------------*/

void    print_hist( stream )
FILE    *stream;
{
        register char **hp = Hist_ptr ;
        register int    i  = Hist_num - MAXHIST ;

        do {
                if( i >= 1 )
                        fprintf(stream, "%3d: %s\n", i, *hp );

                if( ++hp > END )
                        hp = START;

        } while( ++i < Hist_num ) ;
}


/*----------------------------------------------------------------------*/

char    *hist_name( fname )
register char   *fname;
{
        /*      Strip leading white space from fname and then
         *      return a pointer to either the first non-white
         *      character or to DEF_HNAME if there is no
         *      non-white character
```

(Continued on next page)

LISTING TWO **(Listing continued, text begins on page 16)**

```
         */

        while( isspace(*fname) )
                fname++;

        return ( *fname ) ? fname : DEF_HNAME ;
}

/*----------------------------------------------------------------------*/

save_hist( fname )
register char   *fname;
{
        /*      Save the current history list in either the indicated
         *      file or in DEF_HNAME if no file is given.
         */

        register FILE   *fp;

        fname = hist_name( fname );

        if( !(fp = fopen(fname,"w")) )
                perror(fname);
        else
        {
                print_hist(fp);
                fclose(fp);
        }
}

/*----------------------------------------------------------------------*/

restore_hist( fname )
char    *fname;
{
        /*      Add the contents of fname (or DEF_HNAME if fname is
         *      empty) to the history list. Don't execute the
         *      commands.
         */

        register FILE   *fp ;
        register char   *p  ;
        char            *buf ;

        fname = hist_name( fname );

        if( !(fp = fopen( fname, "r" )) )
                perror(fname);

        else if( !(buf = malloc(1024) ))
                fprintf(stderr,"Not enough memory\n");
        else
        {
                while( efgets(buf, 1024, fp) )
                {
                        for(p = buf; isdigit(*p) || isspace(*p); p++ )
                                ;

                        if( *p == ':' )         /* Skip a :<blank> if    */
                                p++;            /* one is present        */
                        if( *p == ' ' )
                                p++;

                        add_hist( p );
#ifdef DEBUG
                        printf("adding %3d: %s\n", Hist_num - 1, p );
#endif
                }

                free( buf );
        }
}

/*----------------------------------------------------------------------*/

void            history( buf, maxbuf )
register char   *buf;
{
        register int    i  = 1  ;
        register char   *p = buf;

        /*      If buf contains a history request (!! ^^ !<num> or ^<num>)
         *      replace its contents as indicated. In any event add the
         *      contents of buf (after the replacement if one was done) to
         *      the history list. Blank lines are ignored. If a history
         *      expansion occures, the expanded line is printed.
         *      Null stings won't be added to the history list.
         */

        if( !*p )
                return;

        if( *p == HIST_CH || *p == EDIT_CH )
        {
                /* First increment p to point at the second character
                 * in the buffer. If the second character in the buffer is
                 * a ! or ^ then i = -1, otherwise it gets the history #.
                 */

                if( *++p == READ_CH )
                {
                        restore_hist( p + 1 );
                        *buf = '\0';
                }
                else if( *p == WRITE_CH )
                {
                        save_hist( p + 1 );
                        *buf = '\0';
```

(Continued on page 70)

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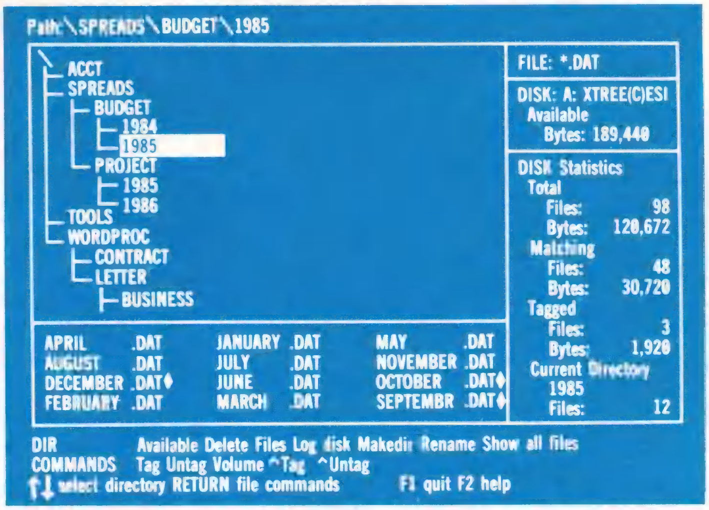

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LISTING TWO **(Listing continued, text begins on page 16)**

```
                }
                else
                {
                        i = (*p == HIST_CH || *p == EDIT_CH) ?  -1: atoi(p);

                        if( *buf == EDIT_CH )
                                i = eget_hist( buf, maxbuf, i);

                        else if( i = get_hist( buf, maxbuf, i) )
                                puts(buf);
                }


                if( !i )
                {
                    fprintf(stderr, "\"%s\" not in history list\n", buf);
                    *buf = '\0';
                }
        }

        add_hist( buf );
}

/*----------------------------------------------------------------------*/

#ifdef DEBUG

main()
{
        /*      Test the history function. Everything typed at the
         *      console is added to the history list and all of
         *      the history expansion functions should work.
         */

        char    buf[132];

        while(1)
        {
                printf("[%d] ", get_hnum() );

                if( !gets(buf) )
                        break;

                history( buf, 132 );

                if( *buf == 'h' && !buf[1] )
                        print_hist( stdout, 0 );
        }
}

#endif
```

End Listing Two

LISTING THREE

```
#include <stdio.h>
#include <ctype.h>

/*      VAR.C           Support for shell variables and aliases.
 *
 *      Copyright (c) 1985, Allen I. Holub. All rights reserved.
 *
 * Externally accessible routines:
 *
 * void unsetvar( name )                        Delete a variable or alias
 * int  setvar( name, val )                     Create/init a variable or alias
 * void printalias()                            Print all aliases
 * void printvars()                             Print all shell variables
 * int  getvar(srcp, destp, maxcount)           Expand a variable or alias
 *
 * The same routines are used for both shell variables and aliases. The
 * latter have the high bit of the first character in the name set.
 */

/*      Isname is true if c is legal in a name. NAMELEN is the maximum
 *      length of a name (additional characters are truncated).
 */

#define isname(c)   (isalnum(c) || (c)=='_' || (c)=='-' || (c)==':')
#define isalias(p)  ( *(p) & 0x80 )

#define NAMELEN  8

typedef struct var
{
        char            name[NAMELEN];
        struct var      *next;
        char            val[1];
}
VAR;

static VAR      *Varlist = NULL ;
static VAR      *Lastvar = NULL ;
extern char     *getenv( char* );

/*----------------------------------------------------------------------*/

static VAR      *findvar( name )
char    *name;
{
```


(Continued on page 72)

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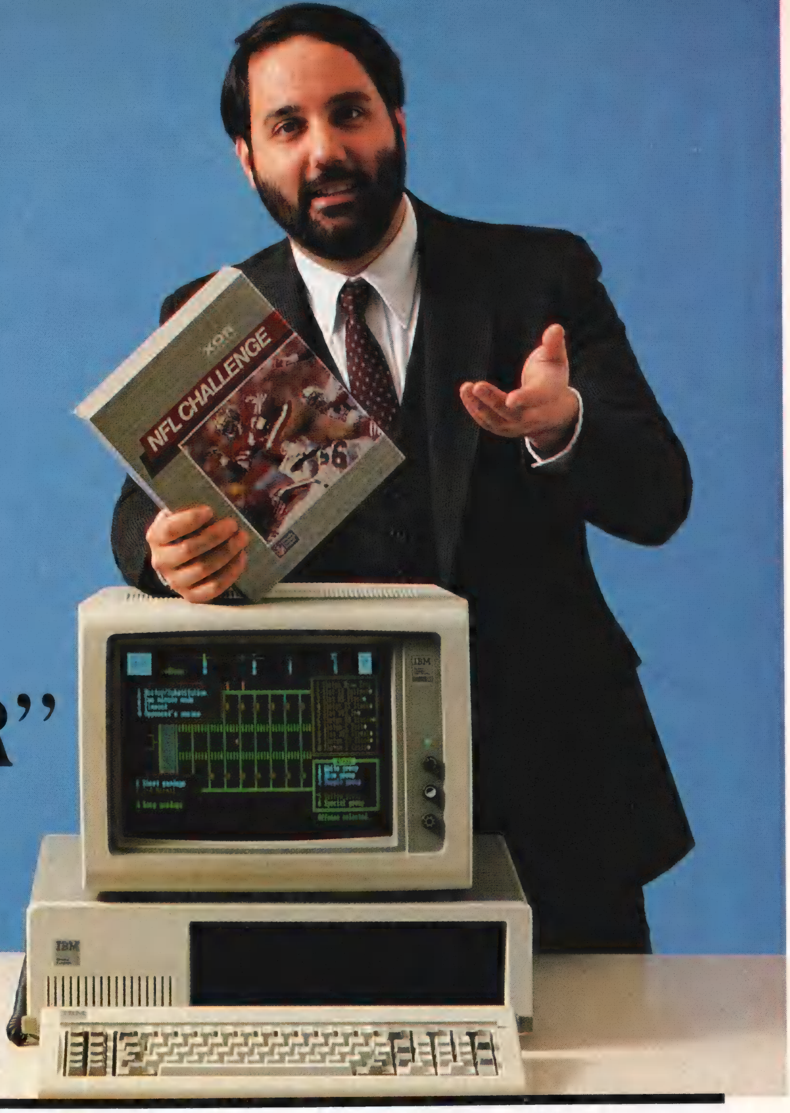

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LISTING THREE **(Listing continued, text begins on page 16)**

```
        /*      Do a search in the Varlist linked list for a
         *      variable called "name." Return a pointer to it if
         *      it exists or 0 if it doesn't.
         */

        register VAR    *p;

        for( p = Varlist; p != NULL ; p = p->next)
                if( !strncmp(name, p->name, NAMELEN) )
                        return p;

        return (VAR *)0 ;
}

/*----------------------------------------------------------------------*/

void    unsetvar( name )
char    *name;
{
        /*      If the variable called name exists, delete it.
         */

        register VAR    *p      = Varlist ;
        register VAR    *lastp  = Varlist ;

        if( !p || !(*name & 0x7f) )
                return;

        for( p = Varlist; p != NULL ; )
        {
                if( !strncmp(name, p->name, NAMELEN) )
                {
                        /* If lastp == p then there's only one
                         * node in the list.
                         */

                        if( lastp == p )
                                Varlist = Lastvar = NULL;
                        else
                        {
                                if( !(lastp->next = p->next) )
                                        Lastvar = lastp;
                        }

                        free( p );
                        break;
                }

                lastp = p  ;
                p = p->next;
        }
}

/*----------------------------------------------------------------------*/

varcpy ( dest , src )
register char   *dest, *src;
{
        /*      Copy src to dest, stripping backslashes and quotes.
         *      as appropriate (ie a \ within a quoted string isn't
         *      stripped.
         */

        int     inquote = 0;

        while( *src )
        {
                if( *src == '\\')
                {
                        if( !inquote )
                                src++;
                        else
                                *dest++ = *src++;

                        if( *src )
                                *dest++ = *src++;
                }
                else if (*src == '"' || *src == '\'')
                {
                        inquote = ~inquote;
                        src++;
                }
                else
                        *dest++ = *src++;
        }

        *dest = 0;
}

/*----------------------------------------------------------------------*/

int     setvar( name, val )
char    *name, *val;
{
        /*      Set the value of the variable "name" to "val". If it
         *      already exists, delete it.
         */

        register VAR    *vp;

        if( !*name )
                return 0;

        unsetvar( name );

        if( !(vp = (VAR *) malloc(sizeof(VAR) + strlen(val))) )
                return 0;
```

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```
        strncpy( vp->name, name, NAMELEN );
        varcpy ( vp->val , val );
        vp->next  = NULL;

        if( !Varlist )
                Varlist = vp;
        else
                Lastvar->next = vp;

        Lastvar = vp;
        return 1;
}

/*----------------------------------------------------------------------
 * All routines in this module may be used for both aliases and shell
 * variables except for the two print routines. Alias's have
 * the high bit if the first character of the name string set.
 */

void printalias()
{
        register VAR    *p;

        for( p = Varlist; p != NULL ; p = p->next)
                if( isalias(p->name) )
                        printf("%c%-8.8s: %s\n",
                                *(p->name) & 0x7f, p->name +1, p->val );
}

void printvars()
{
        register VAR    *p;

        for( p = Varlist; p != NULL ; p = p->next)
                if( !isalias(p->name) )
                        printf("%-8.8s: %s\n",  p->name, p->val );
}

/*----------------------------------------------------------------------*/

int     getvar( srcp, destp, maxcountp )
char    **destp, **srcp;
int     *maxcountp;
{
        /* Expand variable at "*srcp" into destp. Do nothing if
         * the variable doesn't exist, otherwise update srcp to
         * point past the variable name, update destp to point
         * past the end of the expanded variable, and decrement
         * maxcountp by the proper amount.
         *
         * Both shell variables and enviornment variables will be
         * expanded. However, shell variables take presendance
         * over enviornments (they're looked for first).
         *
         * A name can consist of any character in the set
         * {a-zA-Z0-9-_}.
         *
         * If the name is for an alias it will be copied to dest if
         * it can't be expanded, otherwise the name is discarded
         * if it can't be expanded.
         */

        register VAR    *vp;
        char            name[NAMELEN+1];
        register char   *p = name;
        int             i  = NAMELEN;

        /* If the source string is empty or doesn't contain a legit.
         * name then return, doing nothing to dest.
         */

        if( !**srcp || !isname(**srcp & 0x7f) )
                return 0;

        /*      Extract the name from the string at *srcp, updating
         *      *srcp to point past it.
         */

        for( **srcp; isname(**srcp & 0x7f) && --i>=0; *p++ = *(*srcp)++ )
                ;

        *p = 0;

        /*      Now look for the name. If findvar returns true it's
         *      a variable or alias.
         */

        if( vp = findvar(name) )
        {
                /* Expand the alias. Note that the since we
                 * are called from exp_vars, this next
                 * call is a second order recursion.
                 */

                i = exp_vars( *destp, vp->val, *maxcountp, 2 );
                *destp     += i ;
                *maxcountp -= i ;
        }
        else
        {
                /* It's not in the variable table. If we're processing
                 * an alias, copy the name to dest. If we're not
                 * processing an alias, but the variable is in the
                 * envoirnment, then copy the contents of the enviornment
                 * else do nothing.
                 */

                if( p = isalias(name) ? name : getenv(name) )
                {
                        while( *maxcountp > 1  &&  *p )
```

(Continued on next page)

LISTING THREE (Listing continued, text begins on page 16)

```
                        {
                                **destp = *p++ ;
                                (*destp    )++;
                                (*maxcountp)--;
                        }
                }
        }

        **destp = '\0';
}
```

End Listing Three

LISTING FOUR

```
#include <stdio.h>

/*      UNARGV.C        Concatantate all argv entries into a single
 *                      string.
 */

int     unargv( argc, argv, dest, maxcount )
char            **argv, *dest;
register int    maxcount;
{
        /*      Turn argv into a single string, with a single ' ' seperating
         *      each entry. maxcount is the maximum size of dest. Return
         *      the number of characters put into dest.
         */

        register char   *src;
        char            *sdest = dest;

        while( --argc >= 0  && maxcount > 0 )
        {
                for( src = *argv++; *src && --maxcount > 0; )
                        *dest++ = *src++ ;

                if( --maxcount > 0  &&  argc > 0 )
                        *dest++ = ' ';
        }

        *dest = 0;
        return( dest - sdest );
}
```

End Listing Four

LISTING FIVE

```
extern  int     strcpy  ( char*,        char*   );
extern  char    *malloc ( unsigned              );
extern  int     strlen  ( char*,                );


char    *strsave( str )
char    *str;
{
        /*      Save the indicated string in a malloc()ed section
         *      of static memory. Return a pointer to the copy or
         *      0 if malloc failed
         */

        register char *rptr;
        extern   char *malloc();

        if( rptr = malloc( strlen(str) +1 ))
        {
                strcpy( rptr, str );
                return rptr;
        }

        return (char *)0;
}
```

End Listings

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LISTING ONE (Text begins on page 26)

```
{ file polydiv.pas, 85/9/18/tfr (from 9/15,13) }
{ simulation of CRC-type operations }

{ Copyright (c) 1985, T.F. Ritter; All Rights Reserved }

{ generates a binary trace through the polynomial division
{ and crc algorithms to illustrate equivalent results
{ (this assumes we init the remainder reg. to 0) }


{$R+}  { Range Checks ON }

PROGRAM polydiv;

{ first, output through MSDOS, and define binary display }

TYPE
   regs = RECORD
          ax,bx,cx,dx,bp,si,di,ds,es,flags: INTEGER;
          END;

PROCEDURE bdosch( ch: CHAR );
   { output through MSDOS; allow Ctrl-P toggle }
   VAR r: regs;
   BEGIN
   r.ax := $0200;
   r.dx := ORD(ch);
   MsDos( r );
   END;

TYPE
   small = 0..15;

PROCEDURE showbin( x: INTEGER; from, too: small );
   { display subset of integer as binary bits }
   { from and too are place values (15 - 0) left to right }
   VAR i: small;
   BEGIN
   WRITE( ' ' );
   FOR i := 15 DOWNTO 0 DO
      BEGIN
      IF i IN [too..from] THEN
         IF (x < 0) THEN
            WRITE( ' 1' )
         ELSE
            WRITE( ' 0' )
      {
      ELSE
         WRITE( ' x' )
      };
      x := x Shl 1;
      END;
   WRITE( ' ' );
   END; {showbin}


VAR  { globals }
   a: INTEGER;  { the remainder value register; right-aligned }
   p: INTEGER;  { the polynomial; right-aligned }
   d: INTEGER;  { the data; left-aligned }
   deg: small;  { the degree of the polynomial }
   dbits: BYTE; { the number of data bits to process }


PROCEDURE showad( pb: small );
   { show current remainder and next data bit (only) }
   { the data bit on the last step is meaningless }
   BEGIN
   WRITELN;
   showbin( a, (pb - 1), 0 );
   showbin( d, 15, 15 );
   END;


{ start bit-level utilities for crc-type algorithms }


TYPE
   abit = 0..1;


FUNCTION dn: abit;
   { value of next data bit }
   { since d is an INTEGER, "d Shl 1" = "d + d" }
   { use "d := d + d" in other Pascals }
   BEGIN
   IF (d < 0) THEN
      dn := 1
   ELSE
      dn := 0;
   d := d Shl 1;
   END;


FUNCTION an( n: small ): BOOLEAN;
   { value of particular remainder bit }
   { for other Pascals, use a loop and do "x Shl 1" n times }
   { "x Shl 1" must itself be "x + x"; init x to 1 first }
   BEGIN
   an := ((a AND (1 SHL n)) <> 0);
   END;


{ start crc-type algorithms }


PROCEDURE pdiv;
   { mod-2 polynomial division (for remainder only) }
   BEGIN
   IF an(deg - 1) THEN
      a := (a Shl 1) XOR p XOR dn
   ELSE
      a := (a Shl 1) XOR dn;
   END; {pdiv}


PROCEDURE crc;
   { mod-2 remainder without extra zeros }
   BEGIN
   IF (an(deg - 1) XOR (dn <> 0)) THEN
      a := (a Shl 1) XOR p
   ELSE
      a := (a Shl 1);
   END; {crc}


{ start trace displays; show one or the other }


PROCEDURE showpdiv( dbits: BYTE );
   VAR i: BYTE;
   BEGIN
   WRITE( ^M^J'POLYNOMIAL DIVIDE;  Polynomial = ' );
   showbin( p, deg, 0 );
   WRITE( ^M^J'Remainder   Data' );
   showad( deg );
   FOR i := 1 TO dbits DO
      BEGIN
      pdiv;
      showad( deg );
      END;
   WRITELN;
   END;


PROCEDURE showcrc( dbits: BYTE );
   VAR i: BYTE;
   BEGIN
   WRITE( ^M^J'CRC OPERATION;  Polynomial = ' );
   showbin( p, deg, 0 );
   WRITE( ^M^J'Remainder   Data' );
   showad( deg );
   FOR i := 1 TO dbits DO
      BEGIN
      crc;
      showad( deg );
      END;
   WRITELN;
   END;



PROCEDURE init( i: BYTE );
   { select one of the initializations }

   PROCEDURE init1;
      { simulating long division example }
      { from Peterson & Brown, Proc. of the IRE, Jan. 1961, p. 232 }
      BEGIN
      p := $0005;
      deg := 2;
      d := $e800;
      dbits := 6;
      END; {init1}


   PROCEDURE init2;
      { simulating generation of check code }
      { Peterson & Brown, 1961, p. 229 }
      { data are shifted left, so are in reversed order from article}
      BEGIN
      p := $0035;  { the classical example polynomial }
      deg := 5;
      d := $8940;
      dbits := 10;
      END; {init2}


   PROCEDURE init3;
      { simulating published tables }
      { K. Rallapalli, EDN, Sept. 5 1978, pp. 119 - 123 }
      BEGIN
      p := $0035;  { here it is again }
      deg := 5;
      d := $d1b0;
      dbits := 12;
      END; {init3}


   BEGIN {init}
   CASE i OF
      1: init1;
      2: init2;
```

(Continued on page 78)

LISTING ONE

(Listings continued, text begins on page 26)

```
         3: init3;
         END; {case}
      a := 0;
      END; {init}


   { start of the ultimate command code }

   VAR
      i: BYTE;

   BEGIN {main}

   ConOutPtr := Ofs( bdosch ); {allow Ctrl-P printer toggle}

   { for three different initializations . . . }
   FOR i := 1 TO 3 DO
      { show binary trace of pdiv and crc algorithms }
      BEGIN
      init( i );
      showpdiv( dbits + deg );
      init( i );
      showcrc( dbits );
      END;

   END. {main}

   { end file polydiv }
```

End Listing One

LISTING TWO

```
   { file crctime.pas, 85/9/18/tfr (from 9/15, 7/13, 6/27-26,
                        showtime.pas 3/23, 1/4, 84/12/25
                        and showkeys 12/12-11, 11/17
                        and strinkey.pas, 11/17) }
   { compute crc execution times }

   { Copyright (c) 1984, 1985, T.F. Ritter; All Rights Reserved }

   { Please feel free to copy and use the CRC routines, but . . . }
   {     do include the name of the CRC programmer when you do. }
   { The CRC programmer is Terry Ritter. }


   { AIMS: }
   { 1. Display a number of different CRC-CCITT implementations. }
   { 2. Verify identical results. }
   { 3. Collect and display time statistics on each routine. }


   PROGRAM showtime;

   { minimum overhead for speed tests }
   {$R-}  { Range Checks OFF }
   {$C-}  { Ctrl-C Checking OFF }


   PROCEDURE ownership;
      BEGIN
      WRITE( con,
^M^J, 'CRCTIME, 85/9/18',
^M^J, 'Execution times for various CRC implementations.',
^M^J, 'Copyright (c) 1985, T.F. Ritter; All Rights Reserved.',
^M^J     );
      END;



   TYPE
      regs = RECORD
             ax,bx,cx,dx,bp,si,di,ds,es,flags: INTEGER;
             END;
   PROCEDURE bdosch( ch: CHAR );
      { direct console output through MSDOS }
      { allows Ctrl-P printer toggle }
      { also skips Ctrl-C break test }
      VAR
         r: regs;
      BEGIN
      r.ax := $0200;
      r.dx := ORD(ch);
      MsDos( r );
      END;


   { start of time operations }

   TYPE
      timearty = ARRAY[0..3] of INTEGER; {originally had yr, dy}


   PROCEDURE readhms( VAR dt: timearty );
      { Hi(dt[2]) = hrs (0 - 23), Lo(dt[2]) = mins (0 - 59) }
      { Hi(dt[3]) = secs (0 - 59), Lo(dt[3]) = msecs (0 - 99) }
      VAR
         r: regs;
      BEGIN
      r.ax := $2c00;
      MsDos( r );
      dt[2] := r.cx;
      dt[3] := r.dx;
      END; { rddtti }
```


(Continued on page 80)

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LISTING TWO

(Listings continued, text begins on page 26)


```
    FUNCTION timetorealsecs( x: timearty ): REAL;
       BEGIN
       timetorealsecs := (Hi(x[2]) * 3600.0)  +  (Lo(x[2]) * 60.0) +
                         Hi(x[3])  +  (Lo(x[3]) / 100.0);
       END;


    FUNCTION timedif( a, b: timearty ): REAL;
       BEGIN
       timedif := timetorealsecs( b ) - timetorealsecs( a );
       END;


    { start of CRC stuff }
    { byte crc in Turbo Pascal }
    { for MSDOS }


    { METHOD 1:  Pascal Bit-By-Bit }
    { bit manipulation in a high-level-language }
    { simulation of "longhand" division }
    { mostly for verification of other methods }


    PROCEDURE crcittb( VAR a: INTEGER; databit: BOOLEAN);
       { single bit computation; simulate polydiv hardware }
       { other Pascals can replace "a SHL 1" with "a + a" }
       BEGIN
   IF databit = (a < 0) THEN
      a := a Shl 1
   ELSE
      a := (a Shl 1) XOR $1021;  { CRC-CCITT }
   END; { crcittb }


PROCEDURE crcittby( VAR aa: INTEGER; d: INTEGER );
   { whole byte computation }
   VAR
      i: INTEGER;
   BEGIN
   d := d Shl 7;
   FOR i := 7 DOWNTO 0 DO
      BEGIN
      d := d Shl 1;
      crcittb( aa, (d < 0) );
      END;
   END; { crcittby }


{ METHOD 2: Pascal Fast Bit-By-Bit }
{ eliminates procedure-call overhead in the loop }
{ similar to most XMODEM crc implementations}


PROCEDURE crcfbbb( VAR aa: INTEGER; d: INTEGER );
   { fast bit-by-bit whole byte computation }
   VAR
      i: INTEGER;
   BEGIN
   d := d Shl 7;
   FOR i := 7 DOWNTO 0 DO
      BEGIN
      d := d Shl 1;
      IF ((d  XOR aa) < 0) THEN
         aa := (aa Shl 1) XOR $1021
      ELSE
         aa := aa Shl 1;
      END;
   END; { crcfbbb }


{ METHOD 3: Pascal Byte }
{ process the data byte without loops }
{ transportable within Turbo Pascal, and fairly fast }
{ may be slower in Pascals without bit-shifting operations }


PROCEDURE crcitta( VAR dx: INTEGER; data: INTEGER);
   { dx := crcTransform( dx; data ) }
   { polynomial = $11021 }

   { FOR OTHER PASCALS: }
   {       Generate a Swap function "swap( x: INTEGER ): INTEGER" }
   { probably "swap := (x * 256) + (x DIV 256) would work" }
   { Lo(x) = x AND $00ff = x AND 255 }
   { x Shr 4 = x DIV 16 }
   { x Shl 4 = x * 16 }
   { x Shl 5 = x * 32 }

   BEGIN { crcitta }

   dx := Swap( dx ) XOR data;

   dx := dx XOR ( Lo(dx) Shr 4 );

   dx := dx XOR (Swap(Lo(dx)) Shl 4) XOR (Lo(dx) Shl 5);

   END; { crcitta }
```

```
{ METHOD 4: Pascal Table }
{ pull changes from table, indexed by composite value }
{ still faster, but requires the table, and filling the table }
{ may be even faster, relatively, in another Pascal }
{ a slower routine is fine to fill the table }


VAR
   crctab:  ARRAY[0..255] of INTEGER;


PROCEDURE crctablu( VAR crcreg: INTEGER; data: INTEGER);
   BEGIN
   crcreg := Swap(crcreg) XOR data;
   crcreg := (crcreg AND $ff00) XOR crctab[ Lo(crcreg) ];
   END;


PROCEDURE initctab;
   { use method 3 to init the table }
   VAR
      i: INTEGER;
   BEGIN
   FOR i := 0 TO 255 DO
      BEGIN
      crctab[i] := 0;
      crcitta( crctab[i], i );
      END;
   END; {initctab}

{ METHOD 5: Machine Code Byte }
{ method 3 in "Inline" machine code (MSDOS) }
{ typically hidden away in an "Include" file }
{ other Pascals may need to modify the stack interface }


PROCEDURE mcrcittl( VAR dx: INTEGER; data: INTEGER );
   { a := crcTransform( dx; data ) }
   { for MSDOS }
   { polynomial = $11021 }

   BEGIN { mcrcittl }
   INLINE (
             $c4/$7e/<dx/    {  es:di := [bp +"dx"]    }
             $26/$8b/$05/    {  ax := [es:di]          }

   { dx := SWAP(dx) XOR data; }
             $86/$e0/        {  ah <=> al              }
             $33/$46/<data/ {  ax := ax XOR [bp + "data"] }
             $89/$c2/        {  dx := ax               }

   { dx := dx XOR ( LO(dx) SHR 4 ); }
             $d0/$e8/        {  al := al SHR 1         }
             $d0/$e8/        {  al := al SHR 1         }
             $d0/$e8/        {  al := al SHR 1         }
             $d0/$e8/        {  al := al SHR 1         }
             $32/$d0/        {  dl := dl XOR al        }

   { dx := dx XOR ( (SWAP( LO(dx) ) SHL 4 ); }
             $88/$d4/        {  ah := dl               }
             $d0/$e4/        {  ah := ah SHL 1         }
             $d0/$e4/        {  ah := ah SHL 1         }
             $d0/$e4/        {  ah := ah SHL 1         }
             $d0/$e4/        {  ah := ah SHL 1         }
             $32/$f4/        {  dh := dh XOR ah        }

   { dx := dx XOR ( ( LO(dx) ) SHL 5 ); }
             $88/$d0/        {  al := dl               }
             $b4/$00/        {  ah := 0                }
             $d1/$e0/        {  ax := ax SHL 1         }
             $d1/$e0/        {  ax := ax SHL 1         }
             $d1/$e0/        {  ax := ax SHL 1         }
             $d1/$e0/        {  ax := ax SHL 1         }
             $d1/$e0/        {  ax := ax SHL 1         }
             $33/$d0/        {  dx := dx XOR ax        }

             $26/$89/$15     {  es:[di] := dx          } );

   END; { mcrcittl }


{ METHOD 6: Machine Code Table }
{ here the stack parameter interface becomes significant }
{ note the exchange notation "x :=: y" in the comments }


PROCEDURE mcrcitt3( VAR dx: INTEGER; data: INTEGER );
   { a := crcTransform( dx; data ) }
   { for MSDOS }
   { polynomial = $11021 }

   BEGIN { mcrcitt3 }
   INLINE (
             $c4/$7e/<dx/    {  es:di := [bp +"dx"]    }
             $26/$8b/$15/    {  dx := [es:di]          }

   { dx := Swap(dx) XOR data; }
             $86/$d6/        {  dh :=: dl              }
             $33/$56/<data/ {  dx := dx XOR [bp + "data"] }

   { bx := Lo(dx) SHL 1;  dl := 0; }
             $31/$db/        {  bx := bx XOR bx        }
             $86/$d3/        {  bl :=: dl              }
             $d1/$e3/        {  bx := bx SHL 1         }

   { dx := dx XOR crctab[ bx ]; }
             $33/$97/>crctab/  {  dx := dx XOR [bx + "crctab"] }

             $26/$89/$15     {  [es:di] := dx          } );

   END; { mcrcitt3 }
```

(Continued on next page)

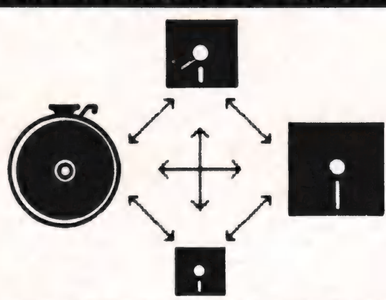
LISTING TWO

(Listings continued, text begins on page 26)

```
{ start of validation testing }

PROCEDURE fultest( beg: INTEGER );
   CONST
      maxpass = 5;
   TYPE
      st40 = STRING[40];
      passtype = ARRAY[ 1..maxpass ] of INTEGER;
   VAR
      adi, pass: INTEGER;
      adr, adt: passtype;

   PROCEDURE overall( VAR a: passtype; t: INTEGER );
      VAR
         x, en, loc: INTEGER;
         data: BYTE;
      BEGIN
      FOR pass := 1 to maxpass DO
         BEGIN
         x := adi;
            CASE pass OF
            1: en := beg;
            2: en := beg + 1;
            3: en := beg + 127;
            4: en := beg + 511;
            5: en := beg + 81;
            END;
         FOR loc := beg TO en DO
            BEGIN
            { a source of data "random" enough for our purposes }
            {   is available in the program code area }
            data := MEM[ Cseg: loc ];
               CASE t OF
               1: crcittby( x, data );
               2: crcfbbb( x, data );
               3: crcitta( x, data );
               4: crctablu( x, data );
               5: mcrcittl( x, data );
               6: mcrcitt3( x, data );
               END; {case}
            END;
         a[pass] := x;
         END;
      END; {overall}

PROCEDURE pbin( value: INTEGER );
   VAR
      i: INTEGER;
   BEGIN
   FOR i := 15 DOWNTO 0 DO
      BEGIN
      IF value < 0 THEN
         WRITE( '1' )
      ELSE
         WRITE( '0' );
      value := value SHL 1;
      END;
   END; {pbin}

   PROCEDURE showres( s: st40 );
      VAR
         errfound: BOOLEAN;
      BEGIN
      errfound := FALSE;
      WRITE( ^M^J'   ', s );

      FOR pass := 1 TO maxpass DO
         IF (adt[pass] <> adr[pass]) THEN
            BEGIN
            errfound := TRUE;
            WRITE( ^M^J'Pass ', pass, ': CRC error.' );
            WRITE( ^M^J, 'Reference:  '); pbin( adr[pass] );
            WRITE( ^M^J, 'Under Test: '); pbin( adt[pass] );
            END;

      IF NOT errfound THEN
            WRITE( ': No error.' );
      END; {showres}

   BEGIN {fultest}
   WRITE( ^M^J^J'BEGIN Validation Testing.' );
   adi := -1;

   initctab;

   overall( adr, 1 );
   WRITE( ^M^J'   Reference = crcittby (Pascal Bit-By-Bit).' );

   overall( adt, 2 );
   showres( 'crcfbbb (Pascal Fast Bit-By-Bit)' );

   overall( adt, 3 );
   showres( 'crcitta (Pascal Byte)' );

   overall( adt, 4 );
   showres( 'crctablu (Pascal Table)' );

   overall( adt, 5 );
   showres( 'mcrcittl (Machine Code Byte)' );

   overall( adt, 6 );
   showres( 'mcrcitt3 (Machine Code Table)' );

   WRITELN( ^M^J'END Validation Testing.' );
   END;  { fultest }
```

```
{ start of timing }


PROCEDURE timetest( loops: INTEGER );
   { organize the time testing of various routines }
   VAR
      a, b: timearty;
      i, x: INTEGER;
      by: BYTE;
      empty: REAL;  { time for empty loops }
      calltime: REAL;  { time for loops and empty procedure }


   PROCEDURE crcmt( VAR dx: INTEGER; data: INTEGER);
      BEGIN
      END;


   PROCEDURE showtimedif( a, b: timearty; c: INTEGER );
      { display a line of time results }
      VAR
         dif, Noloop, NoloopNocall: REAL;

            BEGIN
            dif := timedif( a, b );
            Noloop := dif - empty;
            NoloopNocall := dif - calltime;
            WRITE(
Noloop:7:3, '  ', NoloopNocall:7:3,'          ',
Noloop * (1000.0 / c):7:3, '  ', NoloopNocall * (1000.0 / c):7:3  );
            END; {showtimedif}


         BEGIN {timetest}
         calltime := 0.0;  {the global}
         by := $a5;  {your typical data byte}

         WRITELN(
^M^J^J'Turbo Pascal runs CRC-CCITT on 8088 under Bare MSDOS',
  ^M^J'   FOR ', loops,' OPERATIONS; 7.16 MHz CLOCK
                                     (multiply by 1.5 for 4.77 MHz)' );

         WRITE( ^M^J'Empty loop:  ' );
         readhms( a );
         FOR i := 1 TO loops DO
            ;
         readhms( b );
         empty := timedif( a, b);  {the global}
         WRITE( empty:5:3, ' secs' );

         WRITE( ^M^J'Empty procedure in loop:  ' );
         readhms( a );
         FOR i := 1 TO loops DO
            crcmt( x, by );
         readhms( b );
         calltime := timedif( a, b ); {another global}
         WRITE( calltime:5:3, ' secs' );

         WRITE( ^M^J'   (procedure overhead alone - ',
                (calltime - empty) * (1000.0 / loops):6:3,
                ' msec each)' );

         WRITELN(
^M^J^J'                        ', loops:5, ' Uses (secs)        1 Use
                                                               (msec)',
  ^M^J'               Procedure   In Line    Procedure   In Line' );

         WRITE(
^M^J'Pascal Bit-by-Bit:    ' );
         readhms( a );
         FOR i := 1 TO loops DO
            crcittby( x, by );
         readhms( b );
         showtimedif( a, b, loops );

         WRITE(
^M^J'Pascal Fast B-B-B:    ' );
         readhms( a );
         FOR i := 1 TO loops DO
            crcfbbb( x, by );
         readhms( b );
         showtimedif( a, b, loops );

         WRITE(
^M^J'Pascal Byte:          ' );
         readhms( a );
         FOR i := 1 TO loops DO
            crcitta( x, by );
         readhms( b );
         showtimedif( a, b, loops );

         WRITE(
^M^J'Pascal Table:         ' );
         readhms( a );
         FOR i := 1 TO loops DO
            crctablu( x, by );
         readhms( b );
         showtimedif( a, b, loops );

         WRITE(
^M^J'Machine Code Byte:    ' );
         readhms( a );
         FOR i := 1 TO loops DO
            mcrcittl( x, by );
         readhms( b );
         showtimedif( a, b, loops );

         WRITE(
^M^J'Machine Code Table:   ' );
         readhms( a );
         FOR i := 1 TO loops DO
            mcrcitt3( x, by );
         readhms( b );
         showtimedif( a, b, loops );
         WRITELN;
         END; {timetest}


PROCEDURE datatimes;
   { data character times, for comparison }
   CONST
      rates: ARRAY[1..7] of INTEGER =
            ( 12, 24, 48, 96, 192, 384, 576 );
   VAR i: INTEGER;
   BEGIN
   WRITELN( ^M^J^J'Character Times for Various Bit Rates: ' );
   WRITE( ^M^J'   bits/sec     char/sec    msec/char');
   FOR i := 1 TO 7 DO
      WRITE( ^M^J, '':4, (100.0 * rates[i]):5:0, '':8,
                         (10.0 * rates[i]):5:0, '':8,
                         (100.0 / rates[i]):5:3 );


      WRITELN;
      END; {datatimes}



   BEGIN { main: crctime }
   WRITELN;

   ConOutPtr := OFS( bdosch );  {output through MSDOS}

   ownership;

   fultest( 100 );

   timetest( 10000 );

   datatimes;

   END.
```

End Listings



PASCAL POWERS

LISTING ONE (Text begins on page 36)

```
!
{POWERN.PLB #1.08 85-11-18   INTEGER POWERS OF REALS

  V01 L08 85-11-18 presentation streamlining by DEH.
      L03 update on 85-06-18 by DEH to eliminate one
          always-trivial multiplication by expanding
          on an idea of David Gries.
      L00 created on 85-06-05 by Dennis E.  Hamilton
          to answer a number of electronic  requests
          for help with Pascal powers.              }

function

   PowerN(x: real;   {initial value: x0}
          n: integer {required exponent} )

        :real {value of x0**n};

   var i: integer {non-negative power of x remaining
                   to be computed};
        r: real {running intermediate-result value};

   BEGIN {PowerN}
   if n = 0
   then PowerN := x/x
   else begin {n <> 0}
         i := abs(n);
        {x**i = x0**abs(n)}
         while not odd(i)
            do begin {(x*x)**(i div 2) = x**i}
                x := sqr(x); i := i shr 1;
                end;
         r := x;
        {maintain odd(i) and r*x**(i-1) = x0**abs(n),
         taking r*x**(i-1) = r upon reaching i = 1}
         while i <> 1
            do begin
                repeat
               {(x*x)**(i div 2) = x**(i - i mod 2)}
                   x := sqr(x); i := i shr 1;
                   until odd(i);
               {odd(i) and r*x**i = x0**abs(n)}
                r := r*x;
                end;
        {finally i = 1 and r = x0**abs(n)}
         if n < 0
         then PowerN := 1.0/r
         else PowerN := r;
         end;
   END {PowerN = x0**n};
```

End Listing One

LISTING TWO

```
program TPWRN(out);
     {TPWRN.PAS #1.08 85-11-18 TEST POWERN.PLB CALCULATION OF POWERS

             V01 L08 pretty-print update on 85-09-15 with tidier test output.
                 L02 update on 85-06-20 by DEH to exhibit precision-maintenance
                     difficulties with (1/7)**-i and exp(i*ln(7)) variations.
                 L00 created on 85-06-05 by Dennis E. Hamilton, just for
                     simple confirmation of POWERN's method.}

var    i: integer {counter of trial exponents};
      p7: real {intermediate power of 7 to be checked};
     ln7: real {logarithm of 7 used in comparison with exp(ln) method};
     rv7: real {value of 1/7 used in showing precision loss};
     out: text {file variable used for direction of output as needed};

{$I POWERN.PLB } {Vintage 1.00}
   {Include PowerN here by whatever method the Pascal system supports.
    The above $I pragmat, used with Borland International's Turbo Pascal,
    causes a copy of POWERN.PLB to be included at this point.}

BEGIN {Testing the basic features of POWERN.PLB}
assign(out, 'CON:');
   {Change to a disk-file name when you want to capture the report in
    a file for comparison, uploading, etc.  Implementation-dependent.}
rewrite(out);
writeln(out, 'TPWRN> #1.08 85-11-18 TEST OF POWERN FUNCTION RESULTS');
writeln(out);
                 {....:....1....:....2....:....3....:....4....:....5....:.}
writeln(out,     '       i       (-1)**i     p  = 7**i         (1/7)**-i - p',
                 '       exp(i*ln(7)) - p');
writeln(out);

ln7 := ln(7.0); rv7 := 1.0/7.0;

for i := 0 to 17
 do begin
    write(out, i :8,  PowerN(-1,i) :11:0);
    p7 := PowerN(7.0,i);
       {It  is important to use a number that is prime to the  floating-point
        radix. Although 5 is easier to check mentally, it doesn't show enough
        about accuracy when decimal arithmetic is used, as with Turbo-BCD.}
    write(out, p7 :16:0);
    write(out, PowerN(rv7,-i) - p7 :20:13);
       {Use the known-to-be-inexact reciprocal to show how errors magnify}
    writeln(out, exp(i*ln7) - p7 :21:13);
       {Show deviation of the inefficient exp(i*ln(7)) on the same basis}
    end;
close(out);
END.
```

```
                                                     { . . . }

{

TPWRN> MODIFIED #1.02 85-06-20 TEST OF POWERN FUNCTION RESULTS
       I      (-1)**I       p = 7**I        (1/7)**-I - p       exp(I*ln(7)) - p

       0         1                 1   0.0                      0.0
       1        -1                 7   0.0                     -0.0000000000 146
       2         1                49   0.0000000000 582        -0.000000000 3492
       3        -1               343   0.000000000 9313        -0.00000000 32596
       4         1              2401   0.00000000 74506        -0.0000000 298023
       5        -1             16807   0.0000000 596046        -0.000000 3874302
       6         1            117649   0.000000 8344650        -0.00000 26226044
       7        -1            823543   0.00000 57220459        -0.0000 362396240
       8         1           5764801   0.0000 457763672        -0.000 1296997070
       9        -1          40353607   0.000 3662109375        -0.000 9155273438
      10         1         282475249   0.00 29296875000        -0.0 126953125000
      11        -1        1977326743   0.0 234375000000        -0.0 859375000000
      12         1       13841287201   0. 1875000000000        -0. 6250000000000
      13        -1       96889010407   1. 3750000000000        -4. 2500000000000
      14         1      678223072850  11. 0000000000000       -58. 0000000000000
      15        -1     4747561509900  80. 0000000000000      -400. 0000000000000
      16         1    33232930570000 640. 0000000000000     -1472. 0000000000000
      17        -1   232630513990000 4864. 0000000000000   -20224. 0000000000000

These  results were obtained by assign(out, 'TPWRN.PRN') and  compiling  with
POWERN.PLB #1.03.   CP/M-80 Turbo Pascal version 3.00A was used.   The report
file  was  then incorporated into this edition of TPWRN.PAS as part of  final
editing as a MicroPro WordStar document.   (The WordStar edition is converted
back  to a verified compilable form by "printing" to disk and  filtering  out
all  printing-control information using a simple utility program.)  The  num-
bers  in the error columns have been doctored by addition of spacing to  make
the growth of differences easier to discern.

     Similar  results  should be obtained using MS-DOS,  CP/M-86 and  IBM  PC
versions  of  Turbo Pascal.  Turbo-8087 should obtain better results in  all
columns  because of the greater precision maintained  internally.   Turbo-BCD
should also show improvements, with decreased speed, after the last column is
either  dropped  or library procedures for BCD ln() and exp()  are  obtained.
(For Turbo-BCD and Turbo-8087 both,  it is instructive to increase the number
of decimal positions in the last two columns in order to see what error there
is, however much smaller it turns out to be.)          }

                    (* end of TPWRN.PAS *)
```

End Listings

ADA

LISTING ONE (Text begins on page 42)

```
        LISTING 1 - Draw Poker Program written in Ada

begin
  Open_New(STOCK);
  loop
    put("How many dollars do you want to bet? "); get(WAGER);
    exit when WAGER = 0;
    Shuffle(STOCK);
    Open_New(PLAYERS_HAND);
    for I in 1 .. 5 loop
      Deal_A_Card(PLAYERS_HAND,STOCK);
    end loop;
    put(PLAYERS_HAND);
    Discard_From(PLAYERS_HAND);
    loop
      exit when Filled(PLAYERS_HAND);
      Deal_A_Card(PLAYERS_HAND, STOCK);
    end loop;
    put(PLAYERS_HAND);
    VALUE := Value_Of(PLAYERS_HAND);
    case VALUE is
      when ROYAL_FLUSH => PAYOFF := 250;
      when STRAIGHT_FLUSH => PAYOFF := 50;
      when FOUR_OF_A_KIND => PAYOFF := 25;
      when FULL_HOUSE => PAYOFF := 6;
      when FLUSH => PAYOFF := 5;
      when STRAIGHT => PAYOFF := 4;
      when THREE_OF_A_KIND => PAYOFF := 3;
      when TWO_PAIR => PAYOFF := 2;
      when others => PAYOFF := 0;
    end case;
    if PAYOFF = 0
      then put_line("Sorry, you lose.");
      else put("You have ");put(VALUE);put("!");new_line;
           put("You win"); put(WAGER*PAYOFF); put_line(" dollars!");
    end if;
  end loop;
end Draw_Poker;
```

End Listing One

LISTING TWO

```
------------------------------------------------------------

        LISTING 2 - The general form of a procedure

        procedure *1 is
          *2
        begin
          *3
        exception
          *4
        end *5;
```

End Listing Two

LISTING THREE

```
-----------------------------------------------------------------

        LISTING 3 - The Open_New procedure

  procedure Open_New(DECK : out Decks) is
    i : integer := 0;
    CARD : Cards;
  begin
    for S in Suits loop
      for R in Ranks loop
        CARD.SUIT := S;
        CARD.RANK := R;
        i := i+1;
        DECK.FAN(i) := CARD;
      end loop;
    end loop;
    DECK.CARDS_LEFT := i;
    if i /= CARDS_IN_DECK then raise DECK_ERROR; end if;
  exception
    -- CONSTRAINT_ERROR or DECK_ERROR may be raised by this
    -- procedure if the number of cards in a deck does not
    -- equal the number of cards generated.
    when DECK_ERROR | CONSTRAINT_ERROR =>
      raise DECK_ERROR; -- convert all errors to DECK_ERROR;
  end Open_New;
```

End Listing Three

LISTING FOUR A

```
-------------------------------------------------------------
        Listing 4 (Part A) - PLAYING_CARDS package specification

--                      CARDS.ADA
--                      19 JULY 1984
--                      DO-WHILE JONES

package PLAYING_CARDS is

  CARDS_IN_DECK : constant integer := 52;
  CARDS_IN_HAND : constant integer := 5;

  DECK_ERROR     : exception; -- raised by Open_New
  DECK_EXHAUSED  : exception; -- raised by Deal_A_Card
  HAND_FULL      : exception; -- raised by Deal_A_Card
```

```
  type Suits is (CLUBS, DIAMONDS, HEARTS, SPADES);
  type Ranks is (TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT, NINE, TEN,
    JACK, QUEEN, KING, ACE);

  type Cards is
    record
      SUIT : Suits;
      RANK : Ranks;
    end record;

  type Fans is array(integer range <>) of Cards;
  type Status is array(integer range <>) of boolean;
  type Decks is
    record
      CARDS_LEFT : integer;
      FAN        : Fans(1..CARDS_IN_DECK);
    end record;

  type Hands is
    record
      PLAYED : Status(1..CARDS_IN_HAND);
      FAN    : Fans(1..CARDS_IN_HAND);
    end record;

  function Card_Number(X : integer; HAND : Hands) return Cards;
  function Played_Card_Number(X : integer; HAND : Hands) return boolean;

  function Suit_of(CARD : Cards) return Suits;
  function Rank_of(CARD : Cards) return Ranks;


  procedure put(SUIT : Suits);
  procedure put(RANK : Ranks);
  procedure put(CARD : Cards);
  procedure put(HAND : Hands);


  procedure Open_New(DECK : out Decks);          -- create a new deck
  procedure Shuffle(DECK : in out Decks);        -- shuffle a deck

  procedure Open_New(HAND : out Hands);          -- create a new hand
  procedure Sort(HAND : in out Hands);   -- sort by rank, ignore suits
  procedure Discard_From(HAND : in out Hands);
  function Filled(HAND : Hands) return boolean; -- is the hand full?

  procedure Deal_A_Card(HAND : in out Hands; DECK : in out Decks);

end PLAYING_CARDS;
```

End Listing Four A

(Continued on next page)

ADA

LISTING FOUR B (Listing continued, text begins on page 42)

```
---------------------------------------------------------------
        LISTING 4 (Part B) - PLAYING_CARDS package body

--                        CARDB.ADA
--                        19 JULY 1984
--                        DO-WHILE JONES

with CON_IO; use CON_IO;
with APL; use APL;
package body PLAYING_CARDS is

  CONSTRAINT_ERROR : exception; -- required only by Maranatha A

  function Card_Number(X : integer; HAND : Hands) return Cards is
  begin
    return HAND.FAN(X);
  end Card_Number;

  function Played_Card_Number(X : integer; HAND : Hands) return boolean is
  begin
    return HAND.PLAYED(X);
  end Played_Card_Number;

  function Suit_of(CARD : Cards) return Suits is
  begin
    return CARD.SUIT;
  end Suit_of;

  function Rank_of(CARD : Cards) return Ranks is
  begin
    return CARD.RANK;
  end Rank_of;

  procedure put(SUIT : Suits) is
  begin
  case SUIT is
    when CLUBS => put("CLUBS");
    when DIAMONDS => put("DIAMONDS");
    when HEARTS => put("HEARTS");
    when SPADES => put("SPADES");
  end case;
  end put;



  procedure put(RANK : Ranks) is
  begin
  case RANK is
    when TWO => put("TWO");
    when THREE => put("THREE");
    when FOUR => put("FOUR");
    when FIVE => put("FIVE");
    when SIX => put("SIX");
    when SEVEN => put("SEVEN");
    when EIGHT => put("EIGHT");
    when NINE => put("NINE");
    when TEN => put("TEN");
    when JACK => put("JACK");
    when QUEEN => put("QUEEN");
    when KING => put("KING");
    when ACE => put("ACE");
  end case;
  end put;

  procedure put(CARD : Cards) is
    RANK : Ranks;
    SUIT : Suits;

  begin
    put(Rank_of(CARD)); put(" of "); put(Suit_of(CARD));
  end put;

  procedure put(HAND : Hands) is
  begin
  for i in 1..CARDS_IN_HAND loop
    if Played_Card_Number(i,HAND) then
      null; -- don't display a card that isn't there
    else
      put(Card_Number(i,HAND));
      put("  "); -- separate cards with two blanks
    end if;
  end loop;
  new_line;
  end put;



  procedure Open_New(DECK : out Decks) is
    i : integer := 0;
    CARD : Cards;
  begin
    for S in Suits loop
      for R in Ranks loop
        CARD.SUIT := S;
        CARD.RANK := R;
        i := i+1;
        DECK.FAN(i) := CARD;
      end loop;
    end loop;
    DECK.CARDS_LEFT := i;
    if i /= CARDS_IN_DECK then raise DECK_ERROR; end if;
  exception
    -- CONSTRAINT_ERROR or DECK_ERROR may be raised by this
    -- procedure if the number of cards in a deck does not
    -- equal the number of cards generated.
    when DECK_ERROR | CONSTRAINT_ERROR =>
```

```
    raise DECK_ERROR; -- convert all errors to DECK_ERROR;
end Open_New;

procedure Shuffle(DECK : in out Decks) is
  SEQUENCE : Random_Sequence(1..CARDS_IN_DECK);
  TEMP     : DECKS;
begin
  TEMP.CARDS_LEFT := CARDS_IN_DECK;
  SEQUENCE := Deal(CARDS_IN_DECK, CARDS_IN_DECK);
  for i in 1..CARDS_IN_DECK loop
    TEMP.FAN(i) := DECK.FAN(SEQUENCE(i));
  end loop;
  DECK := TEMP;
end Shuffle;


procedure Deal_A_Card(HAND : in out Hands; DECK : in out Decks) is
  X : integer := 0;
begin
  -- find an empty slot in the hand
  loop
    X := X+1;
    if X > CARDS_IN_HAND then raise HAND_FULL; end if;
    exit when Played_Card_Number(X, HAND);
  end loop;
  -- draw a card from the deck and put it in the empty slot
  if DECK.CARDS_LEFT < 1
    then raise DECK_EXHAUSED;
    else DECK.CARDS_LEFT := DECK.CARDS_LEFT-1;
  end if;
  HAND.FAN(X) := DECK.FAN(CARDS_IN_DECK - DECK.CARDS_LEFT);
  HAND.PLAYED(X) := FALSE;
end Deal_A_Card;

procedure Sort(HAND : in out Hands) is
  SORTED : boolean;
  TEMP : Cards;
begin
  loop
    SORTED := TRUE;
    for i in 1..CARDS_IN_HAND loop
      if Rank_of(Card_Number(i, HAND)) > Rank_of(Card_Number(i+1, HAND)) then
        TEMP := Card_Number(i, HAND);
        HAND.FAN(i) := Card_Number(i+1, HAND);
        HAND.FAN(i+1) := TEMP;
        SORTED := FALSE;
      end if;
    end loop;
  exit when SORTED;
  end loop;
end Sort;
```

(Continued on next page)

LISTING FOUR B **(Listing continued, text begins on page 42)**

```
  procedure Open_New(HAND : out Hands) is
  begin
    for i in 1..CARDS_IN_HAND loop
      HAND.PLAYED(i) := TRUE; -- hand is empty (all cards have been played)
    end loop;
  end Open_New;


  procedure Discard_From(HAND : in out Hands) is
    RESPONSE : character;
  begin
    for i in 1..CARDS_IN_HAND loop
      put("Do you want to discard the ");
      put(Card_Number(i, HAND));
      put("? (Y/N) ");
      get(RESPONSE); new_line;
      if RESPONSE = 'Y' or RESPONSE = 'y'
        then HAND.PLAYED(i) := TRUE;
      end if;
    end loop;
  end Discard_From;

  function Filled(HAND : Hands) return boolean is
  begin
    for i in 1..CARDS_IN_HAND loop
      if Played_Card_Number(i, HAND) then
        return FALSE; -- if any card is played, hand is not filled
      end if;
    end loop;
    return TRUE;  -- if no cards played, hand is filled
  end Filled;

end PLAYING_CARDS;
```

End Listing Four B

LISTING FIVE A

```
          LISTING 5 (Part A) - APL package specification


--                        APLS.ADA
--                        20 JULY 1984
--                        DO-WHILE JONES

--        This package simulates some APL functions.

--        Roll(X) returns a random integer in the range 1..X.

--        Deal(X,Y) returns a random sequence of X elements all
--          of which are in the range 1..Y. No element appears
--          twice in the random sequence.

package APL is

  subtype positive is integer range 1..integer'last;
  -- The above line is not required in Ada.
  -- (It is required for Maranatha A.)

  type Random_Sequence is array(positive range <>) of positive;

  function Roll(LIMIT : positive) return positive;

  function Deal(NUMBER, LIMIT : positive) return Random_Sequence;

end APL;
```

End Listing Five A

LISTING FIVE B

```
          LISTING 5 (Part B) - APL package body


--                        APLB.ADA
--                        20 JULY 1984
--                        DO-WHILE JONES

--        This package simulates two APL functions.

--        Note: Roll uses the RND function which returns a random
--        real number between 0.0 and 1.0. The RND function is
--        implementation specific to Maranatha A.

package body APL is

  function Roll(LIMIT : positive) return positive is
    RANDOM : float;
  begin
    RANDOM := float(LIMIT)*RND(0.0);  -- RND is implementation specific.
    return positive(RANDOM+0.5);
  end Roll;

  function Deal(NUMBER, LIMIT : positive) return Random_Sequence is
    MAX    : positive := LIMIT;
    RS     : Random_Sequence(1..NUMBER);
    SOURCE : Random_Sequence(1..LIMIT);
    RANDOM_INDEX : positive;
  begin
    for i in 1..LIMIT loop
      SOURCE(i) := i; -- SOURCE has one of every number
    end loop;
```

```
    for i in 1..NUMBER loop
      RANDOM_INDEX := Roll(MAX);
      RS(i) := SOURCE(RANDOM_INDEX); -- pick a random number from SOURCE
      for j in RANDOM_INDEX..MAX-1 loop
        SOURCE(j) := SOURCE(j+1); -- remove that number from the SOURCE
      end loop;
      MAX := MAX-1; -- there is now 1 less number in the source array
    end loop;
    return RS;
  end Deal;

end APL;
```

End Listing Five B

LISTING SIX

```
       LISTING 6 - Complete Draw Poker program

--                          DPOKER.ADA
--                          19 JULY 1984
--                          DO-WHILE JONES

with CON_IO; use CON_IO;
with PLAYING_CARDS; use PLAYING_CARDS;
procedure Draw_Poker is

  type Values is (NOTHING, TWO_PAIR, THREE_OF_A_KIND, STRAIGHT,
    FLUSH, FULL_HOUSE, FOUR_OF_A_KIND, STRAIGHT_FLUSH, ROYAL_FLUSH);

  STOCK          : Decks;
  PLAYERS_HAND   : Hands;
  WAGER, PAYOFF  : integer;
  VALUE          : Values;

  procedure put(X : Values) is
  begin
    case X is
      when TWO_PAIR => put("Two Pair");
      when THREE_OF_A_KIND => put("Three of a Kind");
      when STRAIGHT => put("a Straight");
      when FLUSH => put("a Flush");
      when FULL_HOUSE => put("a Full House");
      when FOUR_OF_A_KIND => put("Four of a Kind");
      when STRAIGHT_FLUSH => put("a Straight Flush");
      when ROYAL_FLUSH => put("a Royal Flush");
      when NOTHING => put("a losing hand");
    end case;
  end put;

  function Value_of(HAND : Hands) return Values is separate;

begin
  Open_New(STOCK);
loop
  put("How many dollars do you want to bet? "); get(WAGER);
  exit when WAGER = 0;
  Shuffle(STOCK);
  Open_New(PLAYERS_HAND);
  for I in 1 .. 5 loop
    Deal_A_Card(PLAYERS_HAND,STOCK);
  end loop;
  put(PLAYERS_HAND);
  Discard_From(PLAYERS_HAND);
  loop
    exit when Filled(PLAYERS_HAND);
    Deal_A_Card(PLAYERS_HAND, STOCK);
  end loop;
  put(PLAYERS_HAND);
  VALUE := Value_Of(PLAYERS_HAND);
  case VALUE is
    when ROYAL_FLUSH => PAYOFF := 250;
    when STRAIGHT_FLUSH => PAYOFF := 50;
    when FOUR_OF_A_KIND => PAYOFF := 25;
    when FULL_HOUSE => PAYOFF := 6;
    when FLUSH => PAYOFF := 5;
    when STRAIGHT => PAYOFF := 4;
    when THREE_OF_A_KIND => PAYOFF := 3;
    when TWO_PAIR => PAYOFF := 2;
    when others => PAYOFF := 0;
  end case;
  if PAYOFF = 0
    then put_line("Sorry, you lose.");
    else put("You have ");put(VALUE);put("!");new_line;
         put("You win"); put(WAGER*PAYOFF); put_line(" dollars!");
  end if;
end loop;
end Draw_Poker;
```

End Listing Six

LISTING SEVEN

```
                 LISTING 7 - Value_of subprogram

--                        VALUE.ADA
--                        19 JULY 1984
--                        DO-WHILE JONES

  separate (Draw_Poker); -- real Ada doesn't have a semicolon here
  function Value_of(HAND : Hands) return Values is

    PATTERN : String(1..CARDS_IN_HAND-1);
    X : Hands;

    function Flush_in(HAND : Hands) return boolean is
```

(Continued on next page)

LISTING SEVEN (Listing continued, text begins on page 42)

```
    begin
      for i in 1..CARDS_IN_HAND-1 loop
        if Suit_of(Card_Number(i, HAND)) /= Suit_of(Card_Number(i+1, HAND))
          then return FALSE;
        end if;
      end loop;
      return TRUE;
    end Flush_in;

    function Straight_in(HAND : Hands) return boolean is
    begin
      for i in 1..CARDS_IN_HAND-1 loop
        if Ranks'pos(Rank_of(Card_Numeer(i, HAND)))
         /= Ranks'pos(Rank_of(Card_Number(i+1, HAND)))-1 then
          return FALSE;
        end if;
      end loop;
      return TRUE;
    end Straight_in;

  begin
    X := HAND; -- make a copy of HAND so it can be sorted
    Sort(X);
    for i in 1..CARDS_IN_HAND-1 loop
      if Rank_of(Card_Number(i, X)) = Rank_of(Card_Number(i+1, X)) then
        PATTERN(i) := 'S'; -- adjacent cards have SAME rank
      else
        PATTERN(i) := 'D'; -- adjacent cards have DIFFERENT rank
      end if;
    end loop;
    if Flush_in(X) and Straight_in(X) then
      if Rank_of(Card_Number(5, X)) = ACE then
        return ROYAL_FLUSH;
      else
        return STRAIGHT_FLUSH;
      end if;
    end if;

    if PATTERN = "SSSD" or PATTERN = "DSSS" then
      return FOUR_OF_A_KIND;
    end if;

    if PATTERN = "SSDS" or PATTERN = "SDSS" then
      return FULL_HOUSE;
    end if;

    if Flush_in(X) then
      return FLUSH;
    end if;

    if Straight_in(X) then
      return STRAIGHT;
    end if;

    if PATTERN = "SSDD" or PATTERN = "DSSD" or PATTERN = "DDSS" then
      return THREE_OF_A_KIND;
    end if;

    if PATTERN = "SDSD" or PATTERN = "DSDS" or PATTERN = "SDDS" then
      return TWO_PAIR;
    end if;

    return NOTHING;

  end Value_of;
```

End Listing Seven

LISTING EIGHT

```
         LISTING 8 - Corrected Value_of subprogram

--                    VALUE2.ADA
--                    9 NOVEMBER 1984
--                    DO-WHILE JONES

--       This revision recognizes that TWO, THREE, FOUR,
--       FIVE, ACE is a straight (but not a royal flush).


  separate (Draw_Poker); -- real Ada doesn't have a semicolon
  function Value_of(HAND : Hands) return Values is

    PATTERN : String(1..CARDS_IN_HAND-1);
    X : Hands;

    function Flush_in(HAND : Hands) return boolean is
    begin
      for i in 1..CARDS_IN_HAND-1 loop
        if Suit_of(Card_Number(i, HAND)) /= Suit_of(Card_Number(i+1, HAND))
          then return FALSE;
        end if;
      end loop;
      return TRUE;
    end Flush_in;

    function Straight_in(HAND : Hands) return boolean is
    -- HAND must already be sorted for this procedure to work
    begin
      if Rank_of(Card_Number(1,HAND)) = TWO   and
         Rank_of(Card_Number(2,HAND)) = THREE and
         Rank_of(Card_Number(3,HAND)) = FOUR  and
         Rank_of(Card_Number(4,HAND)) = FIVE  and
         Rank_of(Card_Number(5,HAND)) = ACE then
           return TRUE;
      end if;
```

```
      for i in 1..CARDS_IN_HAND-1 loop
        if Ranks'pos(Rank_of(Card_Number(i, HAND)))
          /= Ranks'pos(Rank_of(Card_Number(i+1, HAND)))-1 then
          return FALSE;
        end if;
      end loop;
      return TRUE;
    end Straight_in;


begin
  X := HAND; -- make a copy of HAND so it can be sorted
  Sort(X);
  for i in 1..CARDS_IN_HAND-1 loop
    if Rank_of(Card_Number(i, X)) = Rank_of(Card_Number(i+1, X)) then
      PATTERN(i) := 'S'; -- adjacent cards have SAME rank
    else
      PATTERN(i) := 'D'; -- adjacent cards have DIFFERENT rank
    end if;
  end loop;
  if Flush_in(X) and Straight_in(X) then
    if Rank_of(Card_Number(4, X)) = KING then
      return ROYAL_FLUSH;
    else
      return STRAIGHT_FLUSH;
    end if;
  end if;

  if PATTERN = "SSSD" or PATTERN = "DSSS" then
    return FOUR_OF_A_KIND;
  end if;

  if PATTERN = "SSDS" or PATTERN = "SDSS" then
    return FULL_HOUSE;
  end if;

  if Flush_in(X) then
    return FLUSH;
  end if;

  if Straight_in(X) then
    return STRAIGHT;
  end if;

  if PATTERN = "SSDD" or PATTERN = "DSSD" or PATTERN = "DDSS" then
    return THREE_OF_A_KIND;
  end if;

  if PATTERN = "SDSD" or PATTERN = "DSDS" or PATTERN = "SDDS" then
    return TWO_PAIR;
  end if;

  return NOTHING;

end Value_of;
```

End Listings

LISTING ONE (Text begins on page 62)

```
MODULE Sorter;

(* Sorter utilizes modules RandomNumbers and Queues to demonstrate *)
(* the utility of data abstraction.                                 *)

FROM InOut IMPORT
                               ClearScreen,
                               WriteInt,
                               WriteLn,
                               WriteString;

FROM RandomNumbers IMPORT
                  (* PROC *) randu;

FROM Queues IMPORT
                  (* PROC *) InitPriorityQueue,
                             QueueEmpty,
                             Add,
                             Fetch,
                  (* TYPE *) PriorityQueue;

VAR Count : CARDINAL;
    x     : INTEGER;
    Q     : PriorityQueue;
BEGIN (* MAIN *)

        ClearScreen;

        InitPriorityQueue(Q); (* Initialize the Priority Queue Q *)

        (* Add 100 pseudo-random numbers to the Priority Queue Q *)
        FOR Count := 1 TO 100 DO
                Add(Q, randu());
        END;

        (* Empty the Priority Queue Q and display each removed element *)
        WriteLn;
        WriteLn;
        WriteString("Sorted Pseudo-Random Numbers.....");
        WriteLn;
        WHILE NOT QueueEmpty(Q) DO
                x := Fetch(Q);
                WriteInt(x, 10);
                WriteLn
        END;

END Sorter.
```

End Listing One

LISTING TWO

```
DEFINITION MODULE Queues;

EXPORT QUALIFIED
                  (* TYPE *)  PriorityQueue,
                  (* PROC *)  InitPriorityQueue,
                              Add,
                              Fetch,
                              QueueEmpty;

TYPE PriorityQueue; (* Opaque Type *)

PROCEDURE InitPriorityQueue(VAR Q : PriorityQueue);
(* Initializes the Priority Queue Q *)

PROCEDURE Add(VAR Q : PriorityQueue; datum : INTEGER);
(* Adds the data item to the Priority Queue Q *)

PROCEDURE Fetch(VAR Q : PriorityQueue) : INTEGER;
(* Fetches the smallest element from the Priority Queue Q *)

PROCEDURE QueueEmpty(Q : PriorityQueue) : BOOLEAN;
(* QueueEmpty RETURNs TRUE if PriorityQueue Q is empty; FALSE otherwise *)

END Queues.

DEFINITION MODULE RandomNumbers;

EXPORT QUALIFIED
        (* PROC *) randu;

PROCEDURE randu() : INTEGER;
(* randu RETURNs a pseud0-random INTEGER *)

END RandomNumbers.
```

End Listing Two

LISTING THREE

```
IMPLEMENTATION MODULE Queues;

FROM Storage IMPORT ALLOCATE, DEALLOCATE;

TYPE PriorityQueue = POINTER TO PriNode;
     PriNode       = RECORD
                          data : INTEGER;
                          link : PriorityQueue;
                     END;
```

```
PROCEDURE InitPriorityQueue(VAR Q : PriorityQueue);
BEGIN
        Q := NIL
END InitPriorityQueue;

PROCEDURE Add(VAR Q : PriorityQueue; datum : INTEGER);
VAR T : PriorityQueue;
BEGIN
        IF QueueEmpty(Q) THEN
                NEW(Q);
                Q^.link := NIL;
                Q^.data := datum;
        ELSIF datum < Q^.data THEN
                NEW(T);
                T^.link := Q;
                T^.data := datum;
                Q := T
        ELSE
                Add(Q^.link, datum)
        END;
END Add;

PROCEDURE Fetch(VAR Q : PriorityQueue) : INTEGER;
VAR tempInt : INTEGER;
    tempQ   : PriorityQueue;
BEGIN
        tempQ := Q;
        tempInt := Q^.data;
        Q := Q^.link;
        DISPOSE(tempQ);
        RETURN tempInt
END Fetch;

PROCEDURE QueueEmpty(Q : PriorityQueue) : BOOLEAN;
BEGIN
        RETURN Q = NIL
END QueueEmpty;

END Queues.


IMPLEMENTATION MODULE RandomNumbers;

VAR x : INTEGER;

PROCEDURE randu() : INTEGER;
BEGIN
        x := (3 * x + 31) MOD 7;
        RETURN x
END randu;

BEGIN
        x := 7;

END RandomNumbers.
```

End Listing Three

LISTING FOUR

```
IMPLEMENTATION MODULE Queues;

FROM Storage IMPORT ALLOCATE, DEALLOCATE;

TYPE PriorityQueue = POINTER TO PriNode;
     PriNode       = RECORD
                             data : INTEGER;
                             link : PriorityQueue;
                     END;
PROCEDURE InitPriorityQueue(VAR Q : PriorityQueue);
BEGIN
        Q := NIL
END InitPriorityQueue;

PROCEDURE Add(VAR Q : PriorityQueue; datum : INTEGER);
VAR T, T1, NewNode : PriorityQueue;
BEGIN
        IF QueueEmpty(Q) THEN
                NEW(Q);
                Q^.link := NIL;
                Q^.data := datum;
        ELSIF datum < Q^.data THEN
                NEW(T);
                T^.link := Q;
                T^.data := datum;
                Q := T
        ELSE
                T := Q;
                WHILE (T # NIL) & (datum >= T^.data) DO
                        T1 := T;
                        T := T^.link;
                END;
                NEW(NewNode);
                NewNode^.link := T;
                NewNode^.data := datum;
                T1^.link := NewNode;
        END;

END Add;

PROCEDURE Fetch(VAR Q : PriorityQueue) : INTEGER;
VAR tempInt : INTEGER;
    tempQ   : PriorityQueue;
BEGIN
        tempQ := Q;
        tempInt := Q^.data;
        Q := Q^.link;
        DISPOSE(tempQ);
        RETURN tempInt
END Fetch;

PROCEDURE QueueEmpty(Q : PriorityQueue) : BOOLEAN;
BEGIN
        RETURN Q = NIL
END QueueEmpty;

END Queues.


IMPLEMENTATION MODULE RandomNumbers;

VAR x : INTEGER;

PROCEDURE randu() : INTEGER;
BEGIN
        x := (5 * x + 31) MOD 4096;
        RETURN x
END randu;

BEGIN
        x := 7;

END RandomNumbers.
```

End Listings

LISTING TWO (Continued from January)

```
fullcy  add.b #$60,rega
        ori #1,ccr
enddaa  move sr,regf
        swap regcon0e
        and.w regcon0f,regf
        move.b 0(flagptr,regf.w),regf
        jmp (return)
nofull  tst.b rega
        bra enddaa

nop28   bra illegl                          ; 28 Illegal for 8080


dadh    move.w regh(regs),d0                ; 29 Dad H
        add.w d0,regh(regs)
        bra docyf

lhld    move.b 1(pseudopc),d0               ; 2A Lhld addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        move.l d0,a0
        adda.l targbase,a0
        move.b (a0)+,regl(regs)
        move.b (a0),regh(regs)
        jmp (return)

dcxh    dec.w regh(regs)                    ; 2B Dcx H
        jmp (return)

inrl    inc.b regl(regs)                    ; 2C Inr L
        move sr,d0
        and.w regcon0e,d0
        and.w regcon01,regf
        or.b 0(flagptr,d0.w),regf
        jmp (return)

dcrl    dec.b regl(regs)                    ; 2D Dcr L
        move sr,d0
        and.w regcon0e,d0
        and.w regcon01,regf
        or.b 0(flagptr,d0.w),regf
        jmp (return)

mvil    move.b (pseudopc)+,regl(regs)       ; 2E Mvi L,nn
        jmp (return)

cma     not.b rega                          ; 2F Cma
        jmp (return)

nop30   bra illegl                          ; 30 Illegal for 8080

lxis    move.b 1(pseudopc),d0               ; 31 Lxi S,nnnn
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        move.l d0,pseudosp
        adda.l targbase,pseudosp
        jmp (return)

sta     move.b 1(pseudopc),d0               ; 32 Sta addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        move.b rega,0(targbase,d0.l)
        jmp (return)

inxs    addq.l #1,pseudosp                  ; 33 Inx S
        jmp (return)

inrm    move.w regh(regs),d0                ; 34 Inr M
        inc.b 0(targbase,d0.l)
        move sr,d0
        and.w regcon0e,d0
        and.w regcon01,regf
        or.b 0(flagptr,d0.w),regf
        jmp (return)
```

```
dcrm    move.w regh(regs),d0                    ; 35 Dcr M
        dec.b 0(targbase,d0.l)
        move sr,d0
        and.w regcon0e,d0
        and.w regcon01,regf
        or.b 0(flagptr,d0.w),regf
        jmp (return)

mvim    move.w regh(regs),d0                    ; 36 Mvi M,nn
        move.b (pseudopc)+,0(targbase,d0.l)
        jmp (return)

stc     bset #0,regf                            ; 37 Stc
        jmp (return)

nop38   bra illegl                              ; 38 Illegal for 8080

dads    move.l pseudosp,d0                      ; 39 Dad S
        sub.l targbase,d0
        add.w d0,regh(regs)
        bra docyf

lda     move.b 1(pseudopc),d0                   ; 3A Lda addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        move.b 0(targbase,d0.l),rega
        jmp (return)

dcxs    subq.l #1,pseudosp                      ; 3B Dcx S
        jmp (return)

inra    move.b rega,regop1(regs)                ; 3C Inr A
        move.b regcon01,regop2(regs)
        move.b regcon0e,regop3(regs)
        inc.b rega
        move sr,d0
        and.w regcon0e,d0
        and.w regcon01,regf
        or.b 0(flagptr,d0.w),regf
```

(Continued on next page)

LISTING TWO (Continued from January)

```
        jmp (return)

dcra    dec.b rega                              ; 3D Dcr A
        move sr,dØ
        and.w regconØe,dØ
        and.w regconØ1,regf
        or.b Ø(flagptr,dØ.w),regf
        jmp (return)

mvia    move.b (pseudopc)+,rega                 ; 3E Mvi A,nn
        jmp (return)

cmc     bchg #Ø,regf                            ; 3F Cmc
        jmp (return)

movebb  move.b regb(regs),regb(regs)            ; 4Ø Mov B,B
        jmp (return)

movebc  move.b regc(regs),regb(regs)            ; 41 Mov B,C
        jmp (return)

movebd  move.b regd(regs),regb(regs)            ; 42 Mov B,D
        jmp (return)

movebe  move.b rege(regs),regb(regs)            ; 43 Mov B,E
        jmp (return)

movebh  move.b regh(regs),regb(regs)            ; 44 Mov B,H
        jmp (return)

movebl  move.b regl(regs),regb(regs)            ; 45 Mov B,L
        jmp (return)

movebm  move.w regh(regs),dØ                    ; 46 Mov B,M
        move.b Ø(targbase,dØ.l),regb(regs)
        jmp (return)

moveba  move.b rega,regb(regs)                  ; 47 Mov B,A
        jmp (return)

movecb  move.b regb(regs),regc(regs)            ; 48 Mov C,B
        jmp (return)

movecc  move.b regc(regs),regc(regs)            ; 49 Mov C,C
        jmp (return)

movecd  move.b regd(regs),regc(regs)            ; 4A Mov C,D
        jmp (return)

movece  move.b rege(regs),regc(regs)            ; 4B Mov C,E
        jmp (return)

movech  move.b regh(regs),regc(regs)            ; 4C Mov C,H
        jmp (return)

movecl  move.b regl(regs),regc(regs)            ; 4D Mov C,L
        jmp (return)

movecm  move.w regh(regs),dØ                    ; 4E Mov C,M
        move.b Ø(targbase,dØ.l),regc(regs)
        jmp (return)

moveca  move.b rega,regc(regs)                  ; 4F Mov C,A
        jmp (return)

movedb  move.b regb(regs),regd(regs)            ; 5Ø Mov D,B
        jmp (return)

movedc  move.b regc(regs),regd(regs)            ; 51 Mov D,C
        jmp (return)
```

```
movedd  move.b regd(regs),regd(regs)            ; 52 Mov D,D
        jmp (return)

movede  move.b rege(regs),regd(regs)            ; 53 Mov D,E
        jmp (return)

movedh  move.b regh(regs),regd(regs)            ; 54 Mov D,H
        jmp (return)

movedl  move.b regl(regs),regd(regs)            ; 55 Mov D,L
        jmp (return)

movedm  move.w regh(regs),dØ                    ; 56 Mov D,M
        move.b Ø(targbase,dØ.l),regd(regs)
        jmp (return)

moveda  move.b rega,regd(regs)                  ; 57 Mov D,A
        jmp (return)

moveeb  move.b regb(regs),rege(regs)            ; 58 Mov E,B
        jmp (return)

moveec  move.b regc(regs),rege(regs)            ; 59 Mov E,C
        jmp (return)

moveed  move.b regd(regs),rege(regs)            ; 5A Mov E,D
        jmp (return)

moveee  move.b rege(regs),rege(regs)            ; 5B Mov E,E
        jmp (return)

moveeh  move.b regh(regs),rege(regs)            ; 5C Mov E,H
        jmp (return)

moveel  move.b regl(regs),rege(regs)            ; 5D Mov E,L
        jmp (return)

moveem  move.w regh(regs),dØ                    ; 5E Mov E,M
        move.b Ø(targbase,dØ.l),rege(regs)
        jmp (return)

moveea  move.b rega,rege(regs)                  ; 5F Mov E,A
        jmp (return)

movehb  move.b regb(regs),regh(regs)            ; 6Ø Mov H,B
        jmp (return)

movehc  move.b regc(regs),regh(regs)            ; 61 Mov H,C
        jmp (return)

movehd  move.b regd(regs),regh(regs)            ; 62 Mov H,D
        jmp (return)

movehe  move.b rege(regs),regh(regs)            ; 63 Mov H,E
        jmp (return)

movehh  move.b regh(regs),regh(regs)            ; 64 Mov H,H
        jmp (return)

movehl  move.b regl(regs),regh(regs)            ; 65 Mov H,L
        jmp (return)

movehm  move.w regh(regs),dØ                    ; 66 Mov H,M
        move.b Ø(targbase,dØ.l),regh(regs)
        jmp (return)

moveha  move.b rega,regh(regs)                  ; 67 Mov H,A
        jmp (return)

movelb  move.b regb(regs),regl(regs)            ; 68 Mov L,B
        jmp (return)

movelc  move.b regc(regs),regl(regs)            ; 69 Mov L,C
        jmp (return)

moveld  move.b regd(regs),regl(regs)            ; 6A Mov L,D
        jmp (return)

movele  move.b rege(regs),regl(regs)            ; 6B Mov L,E
        jmp (return)
```

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LISTING TWO (Continued from January)

```
movelh  move.b regh(regs),regl(regs)          ; 6C Mov L,H
        jmp (return)

movell  move.b regl(regs),regl(regs)          ; 6D Mov L,L
        jmp (return)

movelm  move.w regh(regs),dØ                  ; 6E Mov L,M
        move.b Ø(targbase,dØ.l),regl(regs)
        jmp (return)

movela  move.b rega,regl(regs)                ; 6F Mov L,A
        jmp (return)

movemb  move.w regh(regs),dØ                  ; 7Ø Mov M,B
        move.b regb(regs),Ø(targbase,dØ.l)
        jmp (return)

movemc  move.w regh(regs),dØ                  ; 71 Mov M,C
        move.b regc(regs),Ø(targbase,dØ.l)
        jmp (return)

movemd  move.w regh(regs),dØ                  ; 72 Mov M,D
        move.b regd(regs),Ø(targbase,dØ.l)
        jmp (return)

moveme  move.w regh(regs),dØ                  ; 73 Mov M,E
        move.b rege(regs),Ø(targbase,dØ.l)
        jmp (return)

movemh  move.w regh(regs),dØ                  ; 74 Mov M,H
        move.b regh(regs),Ø(targbase,dØ.l)
        jmp (return)

moveml  move.w regh(regs),dØ                  ; 75 Mov M,L
        move.b regl(regs),Ø(targbase,dØ.l)
        jmp (return)

halt    bsr service                           ; 76 Hlt
        jmp (return)

movema  move.w regh(regs),dØ                  ; 77 Mov M,A
        move.b rega,Ø(targbase,dØ.l)
        jmp (return)

moveab  move.b regb(regs),rega                ; 78 Mov A,B
        jmp (return)

moveac  move.b regc(regs),rega                ; 79 Mov A,C
        jmp (return)

movead  move.b regd(regs),rega                ; 7A Mov A,D
        jmp (return)

moveae  move.b rege(regs),rega                ; 7B Mov A,E
        jmp (return)

moveah  move.b regh(regs),rega                ; 7C Mov A,H
        jmp (return)

moveal  move.b regl(regs),rega                ; 7D Mov A,L
        jmp (return)

moveam  move.w regh(regs),dØ                  ; 7E Mov A,M
        move.b Ø(targbase,dØ.l),rega
        jmp (return)

moveaa  jmp (return)                          ; 7F Mov A,A

addb    move.b regb(regs),dØ                  ; 8Ø Add B
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

addc    move.b regc(regs),dØ                  ; 81 Add C
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

addd    move.b regd(regs),dØ                  ; 82 Add D
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

adde    move.b rege(regs),dØ                  ; 83 Add E
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

addh    move.b regh(regs),dØ                  ; 84 Add H
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega

        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

addl    move.b regl(regs),dØ                  ; 85 Add L
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

addm    move.w regh(regs),dØ                  ; 86 Add M
        move.b Ø(targbase,dØ.l),dØ
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

addaa   move.b rega,regop1(regs)              ; 87 Add A
        move.b rega,regop2(regs)
        move.b regconØe,regop3(regs)
        add.b rega,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

adcb    move.b regf,regop3(regs)              ; 88 Adc B
        asr.b #1,regf
        move.b regb(regs),dØ
        move.b dØ,regop1(regs)
        move.b rega,regop2(regs)
        moveq #Ø,d1
        addx.b dØ,rega
```

```
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adcc    move.b regf,regop3(regs)            ; 89 Adc C
        asr.b #1,regf
        move.b regc(regs),d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adcd    move.b regf,regop3(regs)            ; 8A Adc D
        asr.b #1,regf
        move.b regd(regs),d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adce    move.b regf,regop3(regs)            ; 8B Adc E
        asr.b #1,regf
        move.b rege(regs),d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adch    move.b regf,regop3(regs)            ; 8C Adc H
        asr.b #1,regf
        move.b regh(regs),d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adcl    move.b regf,regop3(regs)            ; 8D Adc L
        asr.b #1,regf
        move.b regl(regs),d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adcm    move.b regf,regop3(regs)            ; 8E Adc M
        move.w regh(regs),d0
        move.l d0,a0
        adda.l targbase,a0
        asr.b #1,regf
        move.b (a0),d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
```

(Continued on next page)

LISTING TWO (Continued from January)

```
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

adca    move.b regf,regop3(regs)          ; 8F Adc A
        asr.b #1,regf
        move.b rega,d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subb    move.b regb(regs),d0              ; 90 Sub B
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subc    move.b regc(regs),d0              ; 91 Sub C
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subd    move.b regd(regs),d0              ; 92 Sub D
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sube    move.b rege(regs),d0              ; 93 Sub E
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subh    move.b regh(regs),d0              ; 94 Sub H
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subl    move.b regl(regs),d0              ; 95 Sub L
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subm    move.w regh(regs),d0              ; 96 Sub M
        move.b 0(targbase,d0.l),d0
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

subaa   move.b rega,d0                    ; 97 Sub A
        sub.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbb    asr.b #1,regf                     ; 98 Sbb B
        move.b regb(regs),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbc    asr.b #1,regf                     ; 99 Sbb C
        move.b regc(regs),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbd    asr.b #1,regf                     ; 9A Sbb D
        move.b regd(regs),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbe    asr.b #1,regf                     ; 9B Sbb E
        move.b rege(regs),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbh    asr.b #1,regf                     ; 9C Sbb H
        move.b regh(regs),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbl    asr.b #1,regf                     ; 9D Sbb L
        move.b regl(regs),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbbm    move.w regh(regs),d0              ; 9E Sbb M
        move.l d0,a0
        adda.l targbase,a0
        asr.b #1,regf
        move.b (a0),d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

sbba    asr.b #1,regf                     ; 9F Sbb A
        move.b rega,d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

andb    move.b regb(regs),d0              ; A0 Ana B
        and.b rega,d0
        move.b d0,rega
        and.w regconff,d0
        move.b 16(flagptr,d0.w),regf
        jmp (return)

andc    move.b regc(regs),d0              ; A1 Ana C
```

```
        and.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

andd    move.b regd(regs),dØ              ; A2 Ana D
        and.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

ande    move.b rege(regs),dØ              ; A3 Ana E
        and.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

andh    move.b regh(regs),dØ              ; A4 Ana H
        and.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

andl    move.b regl(regs),dØ              ; A5 Ana L
        and.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

andm    move.w regh(regs),dØ              ; A6 Ana M
        move.b Ø(targbase,dØ.l),dØ
        and.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

anda    move.b rega,dØ                    ; A7 Ana A
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xrab    move.b regb(regs),dØ              ; A8 Xra B
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xrac    move.b regc(regs),dØ              ; AA Xra C
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xrad    move.b regd(regs),dØ              ; AA Xra D
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xrae    move.b rege(regs),dØ              ; AB Xra E
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
```

(Continued on next page)

LISTING TWO (Continued from January)

```
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xrah    move.b regh(regs),dØ              ; AC Xra H
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xral    move.b regl(regs),dØ              ; AD Xra L
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xram    move.w regh(regs),dØ              ; AE Xra M
        move.b Ø(targbase,dØ.l),dØ
        eor.b dØ,rega
        move.b rega,dØ
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

xraa    moveq #Ø,rega                     ; AF Xra A
        move.b 16(flagptr),regf
        jmp (return)

orab    move.b regb(regs),dØ              ; BØ Ora B
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

orac    move.b regc(regs),dØ              ; B1 Ora C
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

orad    move.b regd(regs),dØ              ; B2 Ora D
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

orae    move.b rege(regs),dØ              ; B3 Ora E
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

orah    move.b regh(regs),dØ              ; B4 Ora H
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

oral    move.b regl(regs),dØ              ; B5 Ora L
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

oram    move.w regh(regs),dØ              ; B6 Ora M
        move.b Ø(targbase,dØ.l),dØ
        or.b rega,dØ
        move.b dØ,rega
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)

oraa    move.b rega,dØ                    ; B7 Ora A
        and.w regconff,dØ
        move.b 16(flagptr,dØ.w),regf
        jmp (return)


cmpb    cmp.b regb(regs),rega             ; B8 Cmp B
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

cmpc    cmp.b regc(regs),rega             ; BB Cmp C
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

cmpd    cmp.b regd(regs),rega             ; BA Cmp D
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

cmpe    cmp.b rege(regs),rega             ; BB Cmp E
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

cmph    cmp.b regh(regs),rega             ; BC Cmp H
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)
```

```
cmpl    cmp.b regl(regs),rega           ; BD Cmp L
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

cmpam   move.w regh(regs),d0            ; BE Cmp M
        move.l d0,a0
        adda.l targbase,a0
        cmp.b (a0),rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

cmpaa   cmp.b rega,rega                 ; BF Cmp A
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

rnz     btst #6,regf                    ; C0 Rnz
        bne mloop
ret     move.b 1(pseudosp),d0           ; C9 Ret
        rol.w #8,d0
        move.b (pseudosp),d0
        addq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)


popb    move.b (pseudosp)+,regc(regs)   ; C1 Pop B
        move.b (pseudosp)+,regb(regs)
        jmp (return)

jnz     move.b 1(pseudopc),d0           ; C2 Jnz addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        btst #6,regf
        bne mloop
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

jmpa    move.b 1(pseudopc),d0           ; C3 Jmp addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

cnz     move.b 1(pseudopc),d0           ; C4 Cnz addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        btst #6,regf
        bne mloop
        move.l pseudopc,d1
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

pushb   move.b regb(regs),-(pseudosp)   ; C5 Push B
        move.b regc(regs),-(pseudosp)
        jmp (return)

adi     move.b (pseudopc)+,d0           ; C6 Adi nn
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        move.b regcon0e,regop3(regs)
        add.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)
```

(Continued on next page)

LISTING TWO (Continued from January)

```
rst0    move.l pseudopc,d1              ; C7 Rst 0
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        move.l targbase,pseudopc
        jmp (return)
rz      btst #6,regf                    ; C8 Rz
        beq mloop
        move.b 1(pseudosp),d0
        rol.w #8,d0
        move.b (pseudosp),d0
        addq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

jz      move.b 1(pseudopc),d0           ; CA Jz addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        btst #6,regf
        beq mloop
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

nopCB   bra illegl                      ; CB Illegal
                                           for 8080

cz      move.b 1(pseudopc),d0           ; CC Cz addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        btst #6,regf
        beq mloop
        move.l pseudopc,d1
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

call    move.b 1(pseudopc),d0           ; CD Call addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        move.l pseudopc,d1
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

aci     move.b regf,regop3(regs)        ; CE Aci nn
        asr.b #1,regf
        move.b (pseudopc)+,d0
        move.b d0,regop1(regs)
        move.b rega,regop2(regs)
        moveq #0,d1
        addx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
```

```
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

rst8    move.l pseudopc,d1                 ; CF Rst 8
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l $8(targbase),pseudopc
        jmp (return)

rnc     btst #Ø,regf                       ; DØ Rnc
        bne mloop
        move.b 1(pseudosp),dØ
        rol.w #8,dØ
        move.b (pseudosp),dØ
        addq.l #2,pseudosp
        lea.l Ø(targbase,dØ.l),pseudopc
        jmp (return)

popd    move.b (pseudosp)+,rege(regs)      ; D1 Pop D
        move.b (pseudosp)+,regd(regs)
        jmp (return)

jnc     move.b 1(pseudopc),dØ              ; D2 Jnc addr
        rol.w #8,dØ
        move.b (pseudopc),dØ
        addq.l #2,pseudopc
        btst #Ø,regf
        bne mloop
        lea.l Ø(targbase,dØ.l),pseudopc
        jmp (return)

out     moveq #Ø,dØ                        ; D3 Out nn
        move.b (pseudopc)+,dØ

        ifne diskio
        cmp.b #$54,dØ
        beq outspec
        cmp.b #$55,dØ
        beq outspec
        endc

        move.l #$ffØØØØ,aØ
        move.b rega,Ø(aØ,dØ.l)
        jmp (return)

cnc     move.b 1(pseudopc),dØ              ; D4 Cnc addr
        rol.w #8,dØ
        move.b (pseudopc),dØ
        addq.l #2,pseudopc
        btst #Ø,regf
        bne mloop
        move.l pseudopc,d1
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l Ø(targbase,dØ.l),pseudopc
        jmp (return)

pushd   move.b regd(regs),-(pseudosp)      ; D5 Push D
        move.b rege(regs),-(pseudosp)
        jmp (return)

sui     move.b (pseudopc)+,dØ              ; D6 Sui nn
        sub.b dØ,rega
        move sr,dØ
        and.w regconØf,dØ
        move.b Ø(flagptr,dØ.w),regf
        jmp (return)

rst1Ø   move.l pseudopc,d1                 ; D7 Rst 1Ø
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
```

(Continued on next page)

LISTING TWO (Continued from January)

```
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l $10(targbase),pseudopc
        jmp (return)

rc      btst #0,regf                            ; D8 Rc
        beq mloop
        move.b 1(pseudosp),d0
        rol.w #8,d0
        move.b (pseudosp),d0
        addq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

nopD9   bra illegl                              ; D9 Illegal
                                                  for 8080

jc      move.b 1(pseudopc),d0                   ; DA Jc addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        btst #0,regf
        beq mloop
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)
in      moveq #0,d0                             ; DB In nn
        move.b (pseudopc)+,d0
        move.l #$ff0000,a0
        move.b 0(a0,d0.l),rega
        jmp (return)

cc      move.b 1(pseudopc),d0                   ; DC Cc addr
        rol.w #8,d0
        move.b (pseudopc),d0
        addq.l #2,pseudopc
        btst #0,regf
        beq mloop
        move.l pseudopc,d1
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l 0(targbase,d0.l),pseudopc
        jmp (return)

nopDD   bra illegl                              ; DD Illegal
                                                  for 8080

sbi     asr.b #1,regf                           ; DE Sbi nn
        move.b (pseudopc)+,d0
        moveq #0,d1
        subx.b d0,rega
        move sr,d0
        and.w regcon0f,d0
        move.b 0(flagptr,d0.w),regf
        jmp (return)

rst18   move.l pseudopc,d1                      ; DF Rst 18
        sub.l targbase,d1
        move.b d1,-2(pseudosp)
        rol.w #8,d1
        move.b d1,-1(pseudosp)
        subq.l #2,pseudosp
        lea.l $18(targbase),pseudopc
        jmp (return)

rpo     btst #2,regf                            ; E0 Rpo
```

```
         bne mloop
         move.b 1(pseudosp),dØ
         rol.w #8,dØ
         move.b (pseudosp),dØ
         addq.l #2,pseudosp
         lea.l Ø(targbase,dØ.l),pseudopc
         jmp (return)

poph     move.b (pseudosp)+,regl(regs)          ; E1 Pop H
         move.b (pseudosp)+,regh(regs)
         jmp (return)

jpo      move.b 1(pseudopc),dØ                  ; E2 Jpo addr
         rol.w #8,dØ
         move.b (pseudopc),dØ
         addq.l #2,pseudopc
         btst #2,regf
         bne mloop
         lea.l Ø(targbase,dØ.l),pseudopc
         jmp (return)

xthl     move.b regl(regs),dØ                   ; E3 Xthl
         move.b (pseudosp),regl(regs)
         move.b dØ,(pseudosp)
         move.b regh(regs),dØ
         move.b 1(pseudosp),regh(regs)
         move.b dØ,1(pseudosp)
         jmp (return)

cpo      move.b 1(pseudopc),dØ                  ; E4 Cpo addr
         rol.w #8,dØ
         move.b (pseudopc),dØ
         addq.l #2,pseudopc
         btst #2,regf
         bne mloop
         move.l pseudopc,d1
         sub.l targbase,d1
         move.b d1,-2(pseudosp)
         rol.w #8,d1
         move.b d1,-1(pseudosp)
         subq.l #2,pseudosp
         lea.l Ø(targbase,dØ.l),pseudopc
         jmp (return)

pushh    move.b regh(regs),-(pseudosp)          ; E5 Push H
         move.b regl(regs),-(pseudosp)
         jmp (return)

ani      and.b (pseudopc)+,rega                 ; E6 Ani nn
         move.b rega,dØ
         and.w regconff,dØ
         move.b 16(flagptr,dØ.w),regf
         jmp (return)

rst2Ø    move.l pseudopc,d1                     ; E7 Rst 2Ø
         sub.l targbase,d1
         move.b d1,-2(pseudosp)
         rol.w #8,d1
         move.b d1,-1(pseudosp)
         subq.l #2,pseudosp
         lea.l $2Ø(targbase),pseudopc
         jmp (return)

rpe      btst #2,regf                           ; E8 Rpe
         beq mloop
         move.b 1(pseudosp),dØ
         rol.w #8,dØ
         move.b (pseudosp),dØ
         addq.l #2,pseudosp
         lea.l Ø(targbase,dØ.l),pseudopc
         jmp (return)
```

(To be continued in March)

LISTING ONE (Text begins on page 114)

```
;***********************************************************************
; PLOTDOT.OBJ   Library module for Microsoft C  (small model programs)
;               by Dan Rollins
;
; Mid-resolution graphics pixel-plot function.
; Uses look-up tables for fastest operation.
; Permission is granted to use this for any purpose whatsoever.
;
; synopsis:
;   plotdot(x,y,color)
;     int x;             horizontal (0-319) not value-checked
;     int y;             vertical (0-199) not value-checked
;     int color;         color for dot (0 to 3)


;------- preamble for placing data into Microsoft C 'S model' static data area
dgroup   group data
data     segment word public 'data'

;-------- lookup table for start of each graphics line
;-------- index is: (Y * 2)
row_tbl   label word
          addr = 0
          rept 100
           dw addr,addr+2000H     ;Y=0,1; 2,3; 4,5; etc
           addr = addr+80
          endm

;-------- lookup table for mid-res pixel positions in relevent byte
;-------- index is: (X mod 4)
mask_tbl  db 00111111b, 11001111b, 11110011b, 11111100b

;-------- lookup table for color, according to position in byte
;-------- index is (COLOR * 4) + (X mod 4)
color_tbl db 00000000b, 00000000b, 00000000b, 00000000b    ;color 0
          db 01000000b, 00010000b, 00000100b, 00000001b    ;color 1
          db 10000000b, 00100000b, 00001000b, 00000010b    ;color 2
          db 11000000b, 00110000b, 00001100b, 00000011b    ;color 3
data      ends

;------- preamble for placing code into Microsoft C 'S model' program area
pgroup   group prog
prog     segment byte public 'prog'
         assume cs:pgroup, ds:dgroup

public   plotdot
plotdot  proc    near              ;SMALL MODEL ONLY
         pop     si                ;fetch return addr /this technique is faster
         pop     bx                ;fetch X ordinate  /than stack-relative access
         pop     di                ;fetch Y ordinate
         pop     cx                ;fetch color

         mov     dx,es             ;save current ES
         mov     ax,0b800H
         mov     es,ax             ;get set to write to video buffer

         shl     di,1              ;index into row address lookup table

         mov     di,row_tbl[di]  ;DI points to start of selected row

         mov     ax,bx             ;copy the X ordinate
         shr     ax,1
         shr     ax,1              ;divided by 4 is byte offset from start of row

         add     di,ax             ;DI points to byte to modify
         mov     al,es:[di]        ;fetch current screen byte

         and     bx,3              ;get pixel-offset in byte (0,1,2, or 3)
         and     al,mask_tbl[bx] ;mask a "hole" into the current byte
;------- index into the color table
         and     cx,3               ;make sure it's a valid color
         shl     cx,1               ; COLOR * 2
         shl     cx,1               ; COLOR * 4
         add     bx,cx              ; index is (COLOR * 4) + (X mod 4)
         or      al,color_tbl[bx] ;fill the "hole" with selected color

         mov     es:[di],al        ;place modified byte back into screen
         mov     es,dx             ;restore caller's ES
         jmp     si                ;artificial (quick) NEAR return to caller
plotdot  endp
prog     ends
         end
```

End Listing One

LISTING TWO

```
/* ******************************************************************
   LINE.C
   by  Dan Rollins
   Uses incremental algorithm and fast ASM plotdot
   Permission is granted to use this for any purpose whatsoever.
****************************************************************** */

_main(arglin)  /* this just skips the 'main' function altogether */
char *arglin;  /* points to the DOS command line */
{
  int x,y;

  dmode(1);  /* enter text mode first (so screen will clear) */
  dmode(4);  /* mid-res color graphics mode */
```

```
  /* test the line algorithm by drawing in all directions, colors */

  for (x=0; x<320; x+=4)  plotline(160,100,  x,  0, 3);
  for (y=0; y<200; y+=4)  plotline(160,100,319,  y, 2);
  for (x=319; x>=0; x-=4) plotline(160,100,  x,199, 1);
  for (y=199; y>=0; y-=4) plotline(160,100,  0,  y, 2);

  getch(); /* pause till key is pressed */
  dmode(2);  /* re-enter text mode */
}

/* *******************************************************************
PLOTLINE(x1,y1,x2,y2,color)
draws a line from (x1,y1) to (x2,y2) in specified color (0 to 3)
calls 'plotdot' (a fast, mid-resolution pixel-plotting routine)
****************************************************************** */
plotline(x1,y1,x2,y2,color)
int x1,y1;    /* starting point */
int x2,y2;    /* ending point */
int color;
{
                                /* use static variables for fastest access */
  static int lg_delta, sh_delta; /* distance of long, short axis */
  static int lg_step, sh_step;   /* 0, 1 or -1 */
  static int cycle;              /* decision variable */
  static int temp;               /* swapping variable */

  lg_delta = x2-x1;              /* get travel along X axis */
  if (lg_delta >= 0)
    lg_step = 1;
  else {
    lg_delta = -lg_delta;        /* get absolute value */
    lg_step = -1;                /* reverse direction */
  }

  sh_delta = y2-y1;              /* get travel along Y axis */
  if (sh_delta >= 0)
    sh_step = 1;
  else {
    sh_delta = -sh_delta;        /* get absolute value */
    sh_step = -1;                /* reverse direction */
  }

  if (sh_delta > lg_delta) {     /* if Y axis is longer, swap axes */
    cycle = sh_delta >> 1;
    temp = lg_delta; lg_delta = sh_delta; sh_delta = temp;
    temp = lg_step; lg_step = sh_step; sh_step = temp;

    while (y1 != y2) {         /* loop for "vertical" line */
      plotpix(x1,y1,color);
      y1 += lg_step;           /* always bump line pointer */
      cycle += sh_delta;       /* bump decision variable */
      if (cycle >= lg_delta) { /* past decision threshold? */
        cycle -= lg_delta;     /* reset for next decison cycle */
        x1 += sh_step;         /* bump column pointer */
      }
    }
  }
  else {                       /* X axis is longer, so don't swap */
    cycle = lg_delta >> 1;
    while (x1 != x2) {         /* loop for "horizontal" line */
      plotpix(x1,y1,color);
      x1 += lg_step;
      cycle += sh_delta;
      if (cycle >= lg_delta) {
        cycle -= lg_delta;
        y1 += sh_step;
      }
    } /* end of while */
  } /* end of else (for axis swap) */
} /* end of plotline */

/* *******************************************************************
DMODE(mode)
sets the display mode
mode is:  0 = bw    40x25 text     4 = color 320x200 graphics
          1 = color 40x25 text     5 = bw    320x200 graphics
          2 = bw    80x25 text     6 = bw    640x200 graphics
          3 = color 80x25 text
****************************************************************** */
dmode(m)
int m;
{
  struct XREGS{ int ax,bx,cx,dx; } regbuf;
  regbuf.ax = m;     /* AH = 0, AL = mode */
  int86(0x10,&regbuf,&regbuf);
}
```

End Listings

Recommended Software

I have been reading about the Smalltalk language with interest for years, but I couldn't quite see my way clear to applying for a job at Xerox's Palo Alto Research Center (PARC) just so I could play with it. METHODS from Digitalk is a true implementation of Smalltalk for the IBM PC (it can't be marketed with the name Smalltalk because of trademark considerations) at a reasonable price.

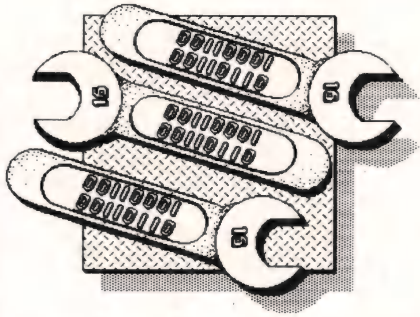
Smalltalk proper is an object-oriented programming language, but Smalltalk as people usually talk about it transcends "mere" coding to become both an environment and a philosophy for programming. The Smalltalk research and related work at Xerox's PARC have become the basis for the much ballyhooed Macintosh user interface and the other windowed, "user-friendly" operating system interfaces that are beginning to show up on microcomputers. Many of its concepts were also incoporated into the language Neon, which was developed for the Macintosh by Kriya Software in Chicago.

METHODS comes with an excellent 550-page manual that leads you gently into this brave but strange new world of object-oriented programming. METHODS' screen performance is snappy, although the implementors had to give up support for bitmapped graphics to attain it; disk performance is OK, but I highly recommend a (large) hard disk. The arrow keys and special-function keys are used in a comfortable way to control the windows, and you can get along without a mouse quite nicely—although a mouse may be used when available.

Readers interested in learning

by Ray Duncan

more about Smalltalk should see the August 1981 special issue of *Byte* and the following books:



Goldberg, Adele. *Smalltalk-80, the Interactive Programming Environment.* Addison-Wesley, 1984.
Smalltalk-80, Bits of History, Words of Advice. Glenn Krasner ed. Addison-Wesley, 1983.
Goldberg, Adele, and Robson, David. *Smalltalk-80, the Language and its Implementation.* Addison-Wesley, 1983.

METHODS can be purchased for $250 from Digitalk Inc., 5200 West Century Blvd., Los Angeles, CA 90045; (213) 645-1082.

Additional Recommended Software

Two days after I received a copy of Microsoft C, Version 3.0, I had abandoned my Lattice C compiler forever. The new Microsoft compiler generates .EXE files that are half the size of the files generated by Lattice C—and faster besides. Microsoft C features extremely good integration with the functions of MS DOS (as you would expect, or at least hope for), including easy access to the environment block and memory management, full path support, and several variations on the exec function. I particularly like the compiler's use of SET strings in the environment to find its libraries and include files.

The Microsoft C floating point libraries use the 8087 or 80287 numeric coprocessor automatically when it is available, or in-line 8087 code can be generated. Unlike Lattice C, a true assembly-language source file can be selected as the output from the C compiler, which may be hand-optimized and then fed to the Microsoft Macro Assembler. The documentation for the compiler, in two volumes, is far and away the best I've seen. I guess you all know where to find Microsoft, so I won't print its address and phone number here.

Pro-CED by Chris Dunford (contributor of many great programs to the public domain, including the BURN-OUT utility) is a command-line editor for PC-DOS with many powerful features including a command stack that allows you to recall and edit previously entered commands for reentry, command synonyms that allow you to abbreviate often-used commands to a few letters or symbols, the ability to chain frequently used commands together without batch files, and on-line help. Pro-CED comes with an excellent manual and is available for $35 from Chris Dunford at P.O. Box 1072, Columbia, MD 21044; (301) 992-9371.

Expanding the Environment

The default environment block provided by COMMAND.COM is not very big, and when you start to use programs that require several SET strings (such as the Microsoft C compiler), you may find that you exhaust the available environment space before you ever get out of the AUTOEXEC.BAT file while you are booting.

Bob Smith, author of the Tall Screen program, has discovered that the DOS 3.1 COMMAND.COM has an undocumented switch to set the size of the environment.

/E:nn sets the size of the environment area to "nn" paragraphs. Range is 10 to 62. Numbers outside that range are ignored.

The default value of the switch appears to be /E:10.

This feature is most useful when used in conjunction with the SHELL option in CONFIG.SYS. For example:

```
SHELL=C:\BIN\COMMAND.COM
        C:\BIN /P /E:20
```

Trojan Horse Programs

Don Watkins, system operator of the CompuServe IBM PC Novice SIG, recently passed me a copy of a Trojan horse program that was uploaded to his bulletin board. This program is named DROGAN.COM and is 7,040 bytes in length. When you run it, it says "Please wait . . .", there is some disk activity, and then it displays "BYE F_HEAD!" and exits—after formatting your disk.

Inspection of DROGAN.COM reveals that it is a "hacked" version of the IBM PC DOS FORMAT.COM program. When you download a program from a BBS without the source code, you need to be really careful—there are some twisted minds out there!

Tom Neff has compiled the following list of other reported Trojan horse programs:

- DOSKNOWS.EXE—FAT killer misleadingly named the same as the harmless DOSKNOWS system-status utility. The real DOSKNOWS is 5,376 bytes long.
- EGABTR—Billed as "improve your EGA display," but when run it deletes everything in sight and prints "Arf! Arf! Got you!"
- FILER.EXE—labeled "Great new filing system," reportedly wiped out 20-meg hard disk.
- SECRET.BAS—Formats disks.
- STRIPES.EXE—Draws an American flag but copies the remote BBS configuration file to another file (STRIPES.BQS) so the uploader can call back and download all the passwords. Clever!
- VDIR.COM—This is the disk killer Jerry Pournelle wrote about in *Byte* magazine.

More on Concurrent DOS

My musings about Digital Research, GEM, and Concurrent PC DOS in recent issues of *DDJ* provoked several heated responses from readers. Evidently many people still harbor warm fuzzy feelings in their heart for Digital Research, dating back to the CP/M 1.4 days, and they suspect that DRI was somehow swindled out of its rightful place as the emperor of microcomputer operating systems. They react violently to the suggestion that DRI might have blown the whole ball game by itself with such brilliant marketing moves as letting CP/M 2.2 stagnate for years, dawdling forever in getting a usable version of CP/M-86 into the field, and wasting valuable time and energy on hot ideas such as Dr Logo.

Well, the statements I've made about GEM and Concurrent PC DOS over the last year in this column are only my own opinions and, of course, do not reflect the opinions of the management of *DDJ*. I have been programming on micros since the CP/M 1.4 days myself, and I certainly appreciate all the contributions Gary Kildall and DRI made with stable, relatively bugfree operating systems and compilers at the beginning of the microcomputer revolution.

The events of the last two or three years, however, seem to point to an organization that is flailing around in the marketplace without much sense of reality or direction. Just recently we have been treated to the sight of DRI starting up massive Unix projects

(Continued from page 115)

and then abandoning them; announcing Protected Mode Concurrent DOS-286 and then fizzling out; caving in to Apple without a battle on the GEM visual interface; dropping support for CP/M-Plus even though the 8080/Z80 operating systems are probably DRI's sole profitable product by now; and spending millions of dollars on advertising to sell only about 50,000 copies of GEM at a price that could have barely covered the costs of materials, packaging, shipping, and handling.

The Concurrent PC DOS project seems to me to be the height of foolishness and a particularly glaring example of DRI's ability to delude itself into believing that the old days can come again. Given the close working relationship between Microsoft and IBM and the frequency with which new IBM hardware products and Microsoft MS DOS versions are released, DRI will always be playing a catch-up game. Even if Concurrent DOS performed as well as MS DOS (which it doesn't), DRI could never hope to be less than six months to a year behind in emulating the functionality of the latest revision of MS DOS—which just isn't going to be good enough for today's software market. DRI would have been much wiser to invest the money and programming talent it put into Concurrent DOS into something that the market really needed instead of into something that DRI wished the market needed.

IBM PC Graphics

Dan Rollins, the prolific author of magazine articles on 8086 assembly language and the book *IBM PC, 8088 Macro Assembler Programming* (Macmillan, 1985), was kind enough to send us the following letter and listings:

"My interest was piqued by Tom Hogan's article 'Using Decision Variables,' published in the May 1985 issue of *DDJ*. I was disappointed in how slow the ellipsis generator executed—far slower than the BASIC CIRCLE command. The code that generates the coordinates is very fast. The bottleneck is in the pixel-plotting subroutine. I thought your readers might appreciate a fast IBM dot plotter to add to their toolboxes.

"The PLOTDOT.ASM program (Listing One, page 112) is different from similar routines in that I have made a concerted effort to cut down on clock cycles. The first thing I did was to remove any 'general code' used to determine the current screen mode, and so on. This version will work only for midresolution graphics.

"But the breakthrough came when I realized that lookup tables could be used to convert the x,y coordinate pair into a screen buffer location and pixel position. This technique eats up some extra RAM (just over 400 bytes), but silicon is cheap. The routine sacrifices storage for speed, and the trade-off is a pretty good deal. It avoids a very time-consuming multi-

plication, and the code is straight-line (there isn't a single conditional jump anywhere in the routine).

"A couple of points of interest in PLOTDOT.ASM. I have written it to interface with Microsoft C Small Model programs, and the start of the code shows the coding overhead required to do so. Second, I have shaved off some precious clock cycles by ignoring the standard interfacing techniques. Instead of the stack relative addressing that is normally used to access parameters, I have simply popped them off the stack into the available registers.

"Another interesting point is in how the main lookup table is generated. This is perhaps the only meaningful use of the Macro Assembler's REPT pseudo-op.

"Finally, I am enclosing a Microsoft C line-drawing function (Listing Two, page 112) that illustrates the speed of the dot plotter. The 'plotline' function uses a decision variable, somewhat similar to that of Hogan's ellipsis generator. You could recode it in assembly language, but it might not be worth your effort. A disassembly shows that the Microsoft compiler generates quite efficient code, which is improved further by using static variables whenever convenient."

More Light Reading

As I mentioned in last month's column, if you don't have a subscription to *Datamation*, you are missing half the fun in life. An example is the essay "Real Programmmers Don't Use Pascal," which appeared in the July 1983 issue on page 263. It introduces itself with:

"The easiest way to tell who the Real Programmers are is by the programming language they use. Real Programmers use FORTRAN. Quiche Eaters use Pascal. Niklaus Wirth, the designer of Pascal, was once asked, 'How do you pronounce your name?' 'You can either call me by name, pronouncing it Veert, or call me by value, Worth,' he replied. One can tell immediately from this comment that Niklaus Wirth is a Quiche Eater. The only parameter passing mechanism endorsed by Real Programmers is call-by-value-return, as implemented in the IBM/370 FORTRAN G and H compilers. Real Programmers don't need abstract concepts to get their jobs done, they are perfectly happy with a keypunch, FORTRAN IV compiler, and a beer. Real Programmers do list processing, string manipulation, accounting (if they do it at all), and artificial intelligence programs in FORTRAN. If you can't do it in FORTRAN, do it in assembly language. If it can't be done in assembly language, it isn't worth doing. . . ."

The article goes on in this vein for four pages, incidentally giving a proof (in FORTRAN, not ALGOL) that Seymour Cray, at least, is a Real Programmer.

Blatant Plug and a Disclaimer

As many of you know, I have been working for a year now on what I hope will be the definitive book on MS DOS programming. It starts where the other books leave off. It is targeted at the experienced assembly-language programmer, and it has many detailed examples and working programs (it contains some C examples, too). Although my own company published this book briefly under the title *MS DOS Internals*, it has now been sold to Microsoft Press and will appear in your favorite bookstore under the title *Advanced MS DOS* in the spring of 1986.

This is not only a plug but also a disclaimer. Although it is a pleasure to be associated with the fine people at Microsoft Press, let me assure you that it will not influence the way I report on Microsoft Corp. software in this column. When the company deserves praise (as with the C compiler), it will get it; and when it deserve brickbats, it'll get those too.

DDJ

(Listings begin on page 112)

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ANNOUNCING! DR. DOBB'S COMPLETE TOOLBOX OF C

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Item #006 or #006A

The Small-C Handbook by James Hendrix is a valuable resource of information about the Small-C Compiler. In addition to descriptions of the language and the compiler, **The Handbook** also contains the entire source listings of the compiler and its library of arithmetic and logical routines. A perfect companion to the Hendrix Small-C compiler offered by Dr. Dobb's on disk, **The Handbook** even tells how to use the compiler to generate new versions of itself. All this is in **The Handbook** for only $17.95, Item #006; only $22.95 for **The Handbook** with the **MS/PC DOS Handbook Addendum**, Item #006A.

While both **The Toolbook** and **The Handbook** provide documentation for the Small-C Compiler on disk, **The Handbook** provides more complete documentation and is available with an Addendum for MS/PC DOS versions.

DR. DOBB'S C TOOLS ON DISK

To complement The Toolbook, *Dr. Dobbs' also offers the following programs on disk. Source code is included, and except where indicated, both CP/M and MS/PC-DOS versions are available.*

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Both **The Toolbook** and **The Small-C Handbook** provide documentation for the compiler; however, **The Handbook** provides more complete documentation for both versions, and the **MS/PC DOS Small-C Handbook Addendum** is recommended in addition to **The Handbook** for MS or PC DOS specific documentation.

Small-Mac: An Assembler for Small-C

Item #012A

Small-Mac is a macro assembler designed to stress simplicity, portability, adaptability, and educational value. The package features simplified macro facility, C-language expression operators, descriptive error messages, object file visibility, and an externally defined machine instruction table. Included programs are: macro assembler, linkage editor, load-and-go loader, library manager, CPU configuration utility, and dump relocatable files. This program is available with documentation in the Small Mac Manual for $29.95. For CP/M systems only.

Small Tools: Programs for Text Processing

Item #010A

This package consists of programs designed to perform specific functions on text files, including: editing, formatting, sorting, merging, listing, printing, searching, changing, transliterating, copying and concatenating, encrypting and decrypting, replacing spaces with tabs and tabs with spaces, counting characters, words, or lines, and selecting printer fonts. Source code only is included. This program is available with documentation in the Small Tools Manual for $29.95. Both CP/M and MS/PC DOS versions available.

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3112B

PROFESSIONAL PROGRAMMER

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"[The company] does warrant the disk.

"The above is the only warranty of any kind, either expressed or implied, including but not limited to the implied warranties of merchantability and fitness for a particular purpose that is made by [the company]."

The above familiar prose is reproduced here without credit to (or permission of) the companies that use it. Although the whole is a composite, every sentence was taken directly from some company's shrinkwrap agreement. There's no point in singling out one or two companies when so many use essentially the same disclaimer. It is routine in software publishing today to sell diskettes for $400 or $500 and inform the purchaser that there may be a piece of software on the diskette; that if there is, it may or may not do what the company's advertising says it will do; that it may or may not do it accurately, correctly, or reliably; and that it may or may not be of any use to anyone; but that in any case it is not the property of the customer, who may be tried as a criminal for any improper use of the product, proper use being defined by the manufacturer.

It's a routine that may soon be shaken—but one organization of software developers is concerned about whose hand will do the shaking.

The Software Services Association (SSA) is a California organization whose members are individuals and companies involved in software development and related fields. It's an explicitly political group that engages in lobbying for the interests of software developers. It was formed in 1982 to fight California's attempt to levy a retroactive sales tax on the work of small software companies that would extend back as far as 1974. The SSA has recently taken on the issue of software warranties, again in connection with proposed legislation.

The California legislature held hearings last summer on a bill (AB 1507) that would have required warranties on all software products. The bill was defeated, but the SSA does not view the issue as closed. Michael Odawa of the SSA was one witness who testified at the hearings. Odawa and the SSA viewed the bill as hostile to the software industry, but Odawa has nevertheless argued in favor of voluntary adoption of warranties and against the practice of using the kind of disclaimers quoted above, contending that companies that use them "apparently feel no need to stand behind their workmanship."

Odawa argues that consumers will not continue to put up with useless warranties much longer, and he cites the legislative battle as evidence. He urges SSA members to offer good warranties and to use them as a marketing tactic. "Put a good warranty on your product," he says, "and tell the world about it. Ask your customers whether the competition stands behind its products."

The SSA publishes a newsletter that details its activities. You can get information about the organization by writing to Software Services Association, P.O. Box 6413, San Jose, CA 95150.

Software Pricing

Another Silicon Valley organization that offers useful services and information for programmers is the Software Entrepreneurs' Forum, which meets monthly in Palo Alto. November's meeting centered on software pricing strategies.

Gregg Marshall, president of Rocky Mountain Systems, tongue only occasionally in cheek, cited seven pricing strategies, each of which prevails over others in some market.

Several of the techniques were textbook or commonsense techniques, such as retail price equals n times cost of goods sold. Marshall set n at somewhere between 6 and 10; in other industries it is often more like 5. Other common techniques included copying the competition, pricing according to the value of the data your software juggles, and selling to the perceived value. The last idea can be particularly appealing to those in a company who see their job as manipulating the public's perception of the product. Other strategies included what Marshall called the Borland strategy of picking a magic number.

Other speakers pointed out that some price ranges create misleading impressions for consumers and that customers are willing to pay for upgrades, willing enough that there are profits to be made from upgrades. Gary Carlston, cofounder of Broderbund, emphasized the importance of involving dealers in the pricing process.

The Software Entrepreneurs' Forum has several splinter groups, such as SIGs covering technical issues for Macintosh and IBM developers, as well as marketing and engineering SIGs. The Forum also publishes a newsletter. You can find out about it by writing to Software Entrepreneurs' Forum, P.O. Box 61031, Palo Alto, CA 94306.

DDJ

CHIPWATCH

Trading Places

A flurry of post-Comdex visits to and from representatives of companies not generally thought of as software developers has left us with a curious impression: programmers and semiconductor producers are trading places.

All right, we're exaggerating. But we do so to emphasize a growing trend, one implication of which is that programmers should keep a close eye on semiconductor firms—and not just to see what new processors are coming. The design of chips is becoming more and more a software task, and the manufacturers of chips are beginning to realize that they need to be in the software business.

Take Intel. We flew up to Oregon to visit some Intel people and learned about some changes underway there.

For years, Intel has sold development systems to its customers, development systems that were, in fact, personal computers. Intel was not, however, in the commercial personal computer marketplace because its machines were built in low volumes for specific purposes. Intel was not building machines that could compete in the commercial market, nor did the company want to be in that market. Intel had decided as far back as the mid-70s that it was not a computer company and it was not in its best interest to develop a commercial computer and compete with its customers.

But the development systems Intel built, the systems it sold to its customers who were building machines around Intel's chips, were not just boxes. Intel also supplied the development software. The history of Intel's involvement in microcomputer software development is rich in intriguing might-have-beens. One of the first Intel development systems sat in the back of Gary Kildall's classroom at the Naval Postgraduate Research Institute in Monterey, California, where graduate student Gordon Eubanks wrote CBASIC as a class project. Kildall wrote some of Intel's development software, and Intel could have had CP/M if it had wanted it. But Intel didn't want a commercial product; it wasn't in the software business any more than it was in the computer business.

Intel passed up CP/M, but it did put together for each of its products a support package of the hardware and software necessary to use the product. The software, like the hardware, was designed for the development phase. In software, as in computers, Intel was just selling support tools for its products, not competing in the commercial market.

Now that's changing. Intel is coming to believe that it belongs in the commercial system-software market and that it must develop competitive products. Company employees make no mystery about the reason for the shift in strategy: it's the IBM PC/AT.

As long as you had to buy Intel's box to use Intel's chips and Intel's software was written to run on Intel's box, the firm had a captive market for its development hardware and software. The AT has cut a link out of the chain: it provides the speed, memory, and power needed for system development, and it makes the Intel boxes unnecessary. Which leaves the software with its chain dangling. Intel development software must now compete with commercial software. That has caused some concern at Intel as well as some scrambling to get the products and the marketing of the products in line with commercial standards and practices. One Intel representative breathed a sigh of relief that *DDJ* had not reviewed the Intel C compiler in its August 1985 review but expressed interest in having the next version included in the next review.

The other side of this coin is that the design of chips (and of computers) is becoming more and more a software task. Two examples of this are silicon compilers and the software simulation of semiconductor devices.

We went to hear David Johannsen speak during Comdex. Johannsen is generally credited with inventing the concept of silicon compilation as a graduate student at Cal Tech. He subsequently cemented his right to use the term by starting a company called Silicon Compilers, which develops silicon compilers (as one might naively guess) and, more recently, silicon compiler compilers. Johannsen's approach to computer-aided design most blatantly underscores the parallels between semiconductor design and software design.

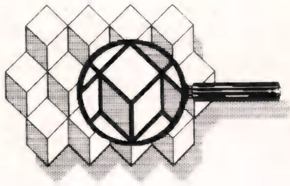
Silicon compilation helps in the design and design testing of a chip just as a software compiler helps in the design of a program. The user works with low-level primitives such as ALUs, RAMs, and PLAs, building these into blocks and modules and perhaps into chips that serve as board-level primitives for a higher level of design. The notion of multiple levels is central to the silicon compiler; the user can design at different levels, with the system simulating devices down only to the level at which design is taking place.

Silicon compilation offers some capabilities that software compilers don't and perhaps should. Users of a silicon compiler can specify designs in language format, just as when writing code (or constructing truth tables, logic equations, microcode; Johannsen classifies all these approaches as language formats). But they can also work at a graphic, more intuitive level, specifying via schematics. And for conventional components, the user has the option of simply filling in a displayed form with on line help—programming by menus.

Silicon Compilers' silicon compilers provide some other softwarelike capabilities, including a rough equivalent of syntax checking in a logical design rule checker (LDRC). The LDRC checks for timing inconsistencies and type inconsistencies (clock expected, ground wired) and flags certain "questionable practices" (mostly nonportable stuff).

DDJ

OF INTEREST



This issue focuses on Pascal, Ada, and Modula-2 as structured languages. There has for some time been a language available in the 6502 world that embodies such structured features as syntactically meaningful indentation: Promal.

Systems Management Associates announced that its Promal 2.0 integrated programming system will support the IBM PC and compatibles by March 1986. Significant performance and capacity enhancements are expected. The product consists of a high-performance, compiled structured language; full-screen editor; operating system executive (except IBM version); and library subroutines. It currently supports the Apple IIc or IIe (with 128K and 80-column card) and the Commodore 64/128.

The Commodore and Apple versions are priced between $50 and $100. The IBM PC line version costs $99.95 plus $5 for shipping and handling.

Control-C Software has announced a software product that permits specific IBM PC applications such as Lotus 1-2-3, Multimate, WordStar, and SideKick to work on personal computers that are not IBM-compatible. Known as Softclone, this software requires no changes to the original release disk, so any copy protection used remains in force.

At the heart of Softclone is a smart loader program that loads the IBM PC application and surrounds it with a fake IBM PC software/hardware environment. Whenever an application accesses IBM-specific memory or hardware, Softclone intervenes, accessing the nonclone host memory, hardware, and operating system instead. Under a licensing agreement, the per-CPU royalty is $10.

Advanced Trace86 from Morgan Computing provides assembly-language programmers with a debugging environment for the IBM PC or IBM PC/AT. In Trace mode, it displays a full screen (16—22 lines) of disassembled code. An inverse video bar marks the instruction that is currently executing. Windows show a constant display of registers and flags, the current stack, and up to six lines of memory (which you can set to track program references). An optional window displays the contents of 8087 registers. It is possible to single step, trace at normal trace speed (about 30 instructions per second) or quick trace speed (about 1/3000 of native), use a keyboard interrupt to start tracing a running program, or set a breakpoint in the code. Advanced Trace86 can also step backward up to 20 instructions to get a replay of the action.

Real-Time Computer Science Corporation has announced several new products. The PL/M Connection is an interface library of more than 150 functions and utilities that provides a direct connection between an IBM PC and Intel's PL/M 86 compiler. PL/M Connection comes on a 360K IBM PC DOS formatted disk, complete with source code in PL/M and assembly, demonstration programs (also with source code), and a 200-page manual. The license fee is $295 per user system.

Version 3.0 of iSIM85 software allows developers to run Intel 8-bit compilers, assemblers, and utilities on IBM PC/XT/ATs or any MS DOS-based computer. It supports Intel development software for the 8085, 8080, 8089, and 8048/8051 processor lines.

Intel and Advanced Computer Techniques have agreed to develop an 80286-based Ada compiler. Aimed at military software design applications, the Ada-286 compiler will support two target environments: the 80286 microprocessor chip and the iRMX286 operating system. Both environments will support the M80287 numeric data processor.

The Advanced Logic Research System 286 is based on the advanced 80286-8 16-bit microprocessor with a system clock rate of 8 MHz. It is designed to be IBM PC/AT bus compatible with full attention to the BIOS ROMs. The system supports IBM PC DOS 3.0 and 3.1 and Xenix operating systems.

A 5-inch board that fits into one IBM "short" slot, the PC/Short Memory from Emulex expands the IBM PC or compatibles to a full memory capacity of 640K. It offers starting addresses of 128K, 256K, 384K, and 512K so the board can work on a variety of personal computers with different RAM capacities on their motherboards. The PC/Short Memory also supports byte parity to protect data in the event of a failure.

Micro Computer Technologies has introduced what it calls the next generation of expansion boards for the IBM PC/XT. The Modular Expansion Series includes an externally mounted visual/audible indicator for keyboard, keylock positions, fast/slow speed, programmable key function, and an added four feet of keyboard extension cable. No IBM expansion slot is required.

The power to develop transportable applications on a range of hardware, including the IBM PC AT, IBM PC XT, and Unix machines, is available through Progress from Data Language. Progress is an application development system combining a fourth-generation application language with a database management system. Advanced facilities provide a single productive environment for building transaction-oriented applications without conventional programming. Its multiuser, environment supports simultaneous database access and update while maintaining database integrity through systems failures.

The Cauzin Softstrip System is for entering, storing, and distributing data. It is an alternative to diskettes and telecommunications. The Softstrip data strips are decoded and entered into a personal computer via an optoelectronic scanning device that plugs into IBM, Apple II series, and Macintosh personal computers. Each data strip can

hold up to 5,500 bytes and can be linked for lengthy programs, financial information, or databases.

Advanced Digital Corporation's PC-Slave II is a high-speed (8 MHz), 16-bit single-board processor that contains two Intel 80188 CPUs, two 512K memory chips, 2K of dual port networking, and a priority interrupt controller. It achieves both hardware and software compatibility with the IBM PC and compatibles by providing functional identity I/O addresses, video display, keyboard interface, and operating system software. Single-user systems can be expanded to multiuser systems of 2–32 individual workstations.

Sumitronics has released the General Purpose Cross Assembler, XASS-V. In addition to supporting programming for all common microprocessors, the XASS-V also supports custom CPUs. Definition files are generated by the option program of the Definition Processor (XGEN-V). It is executable in the 32-bit native mode of VAX-II series and micro VAX-I/II.

Version 1.5 of Koch Software's PC Sweep disk/file management program features an unerase capability that supports fixed and removable hard disks. PC Sweep is an enhanced MS DOS version of the Sweep CP/M software program, and runs on the IBM PC/XT/AT. The product allows users to search for files and determine memory usage of each file, view or page through document files, and access the main menu of help screens via one-key commands.

WATFOR-77, the latest member of the WATFOR family of FORTRAN compilers, has been released by WATCOM Products for the IBM PC DOS operating system. By eliminating the need to produce object files and the linking process, WATFOR-77 can be used to develop and debug programs. The PC version is available for a one-time license fee of $295. A site can be licensed for $1,200 (up to 20 computers) or for $3,000 (more than 20 computers) annually.

Micro Data Base Systems has introduced Guru, an artificial-intelligence software package developed for businesses operating in an IBM PC environment. Guru integrates expert systems capabilities and a natural-language interface with business tools such as spreadsheets, database managers, telecommunications, and text processors.

Multiple ports on the Microfazer II from Quadram provide parallel/parallel, parallel/serial, serial/serial, and serial/parallel modes in a single unit. It has an 8K memory that can be expanded in increments of up to 2 megabytes. Microfazer II buffers print data without using up any of the computer's memory. It then takes over the printing task, freeing the computer.

The CLASIX MultiDrive Director from Reference Technology is designed to increase the number of CD-ROM drives attached to a personal computer. The Director connects up to eight DataDrive Series 500 optical disk drives to a single IBM PC/XT/AT or compatible.

MicroMotion MasterFORTH 1.2 for the IBM PC line now supports the 8087/80287 math coprocessors. The 8087 extension includes a macro assembler with local labels supporting all precisions, opcodes, and synchronization. The floating-point package includes transcendental and high-level functions as well as formatted input and output routines. MasterFORTH 1.2 includes a full file interface to MS DOS 2.1–3.1. It is also available for the Macintosh, the Apple II line, the Commodore 64, and CP/M machines.

Protecting Data

What happens to all that information in the event of a power failure? Elgar has released Failsafe, a microcomputer power-protection device. When utility power fails, Failsafe is activated. After power is restored, it returns the program to where it left off and completes unfinished tasks.

Fastback (Version 5.0) is a hard disk backup software utility from Fifth Generation Systems that backs up a 10-megabyte hard disk on standard 5¼-inch floppies or on the IBM PC/AT. It works with PC DOS or MS DOS, Versions 2.0 or later.

Emerald Systems' Archival Storage Protector supports Novell local area networks, including Netware special files. The utility is available with Emerald ¼-inch tape backup subsystems for both stand-alone and networked IBM-compatible microcomputers. Volumes range from 30 to 236 megabytes of formatted capacity.

Everex has added two memory expansion boards for the IBM PC/AT and compatibles. The RAM 2500AT holds 2½ megabytes of memory (using 64K RAM chips), and the RAM 3000 AT holds 3 megabytes and can use 64K or 256K chips.

Kustom Electronics has introduced the Sunflower MS 10 IR, an internal 10-megabyte removable hard disk kit designed for the IBM PC/XT/AT and AT&T 6300. It is suitable for companies and government agencies handling sensitive or classified data.

Communications

Network Revelation from Cosmos is a transaction-oriented applications environment for microcomputer networks. It uses two filing systems: ROS and Link. ROS is designed for single-user and unshared network files. Link arranges data into 1K frames and allows network locking routines to be used.

The 1200PA, a 212A-compatible modem from Racal-Vadic is designed to solve application problems encountered in dial-up modems. A full dialing keyboard permits control, option setting, dialing, and running diagnostics from the front panel, eliminating pencil switches or dependence upon terminal protocols.

Torus' icon-based networking software system, Tapestry, runs unmodified on IBM's Token Ring networking hardware. The product integrates the functions of file and record management, electronic mail, an independent library of single-user and multiuser applications software, telephone management, shared printers and modems, and other tools.

The Zoom Telephonics Zoom/Modem PC 1200 for the IBM PC/XT/AT and compatibles features call-progress tone detection, real-time clock/calendar, auto-answer touch-tone password security, audio input port, RAM buffer for background electronic messaging, support of four COM ports, and a high-speed 16450 UART for compatibility with the IBM PC/AT and AT clones.

The Software Link's

Z80 CP/M USERS TAKE HEART! HERE'S ALL YOU NEED TO WRITE YOUR OWN PROGRAMS FOR ONLY: $25.00!

DR. DOBB'S Z80 TOOLBOOK

By David E. Cortesi

Do you use CP/M? Do you feel as if the only part of the computer industry that has *not* abandoned you is your own Z80 computer? It keeps on working, but when you need programs for it, you have to write them yourself. When you do, you quickly find that while Pascal or Basic is okay for some things, there is often no substitute for the speed, small size, and flexibility of an assembly language program.

DR. DOBB'S Z80 TOOLBOOK puts the power of assembly language in the hands of anyone who's done a little programming. You'll find:

- **A method of designing programs and coding them in assembly language**—and—a demonstration of the method in the construction of several complete, useful programs.

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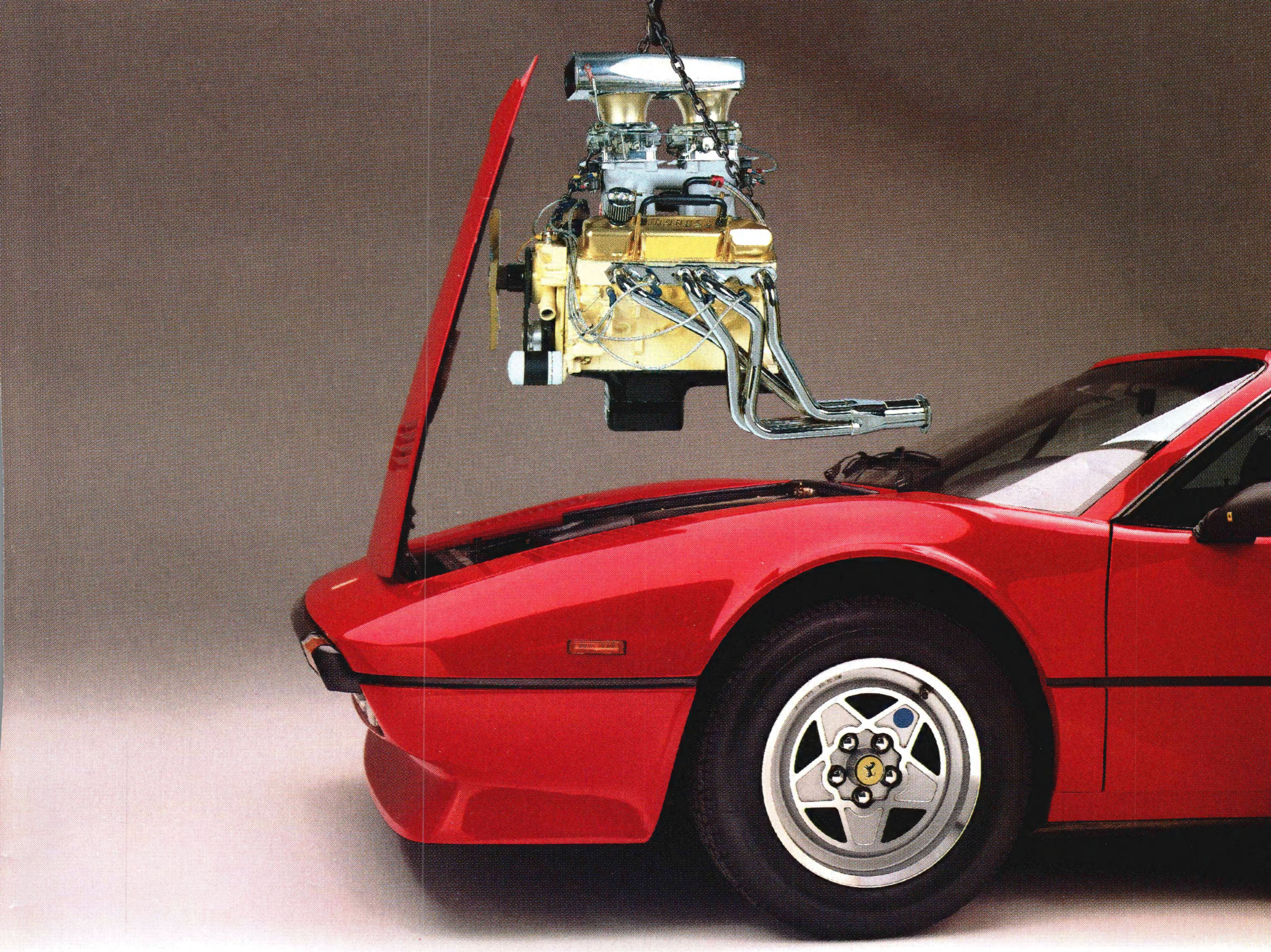

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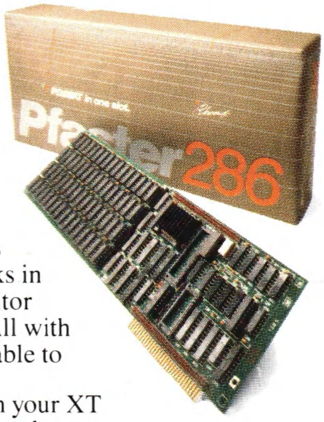

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